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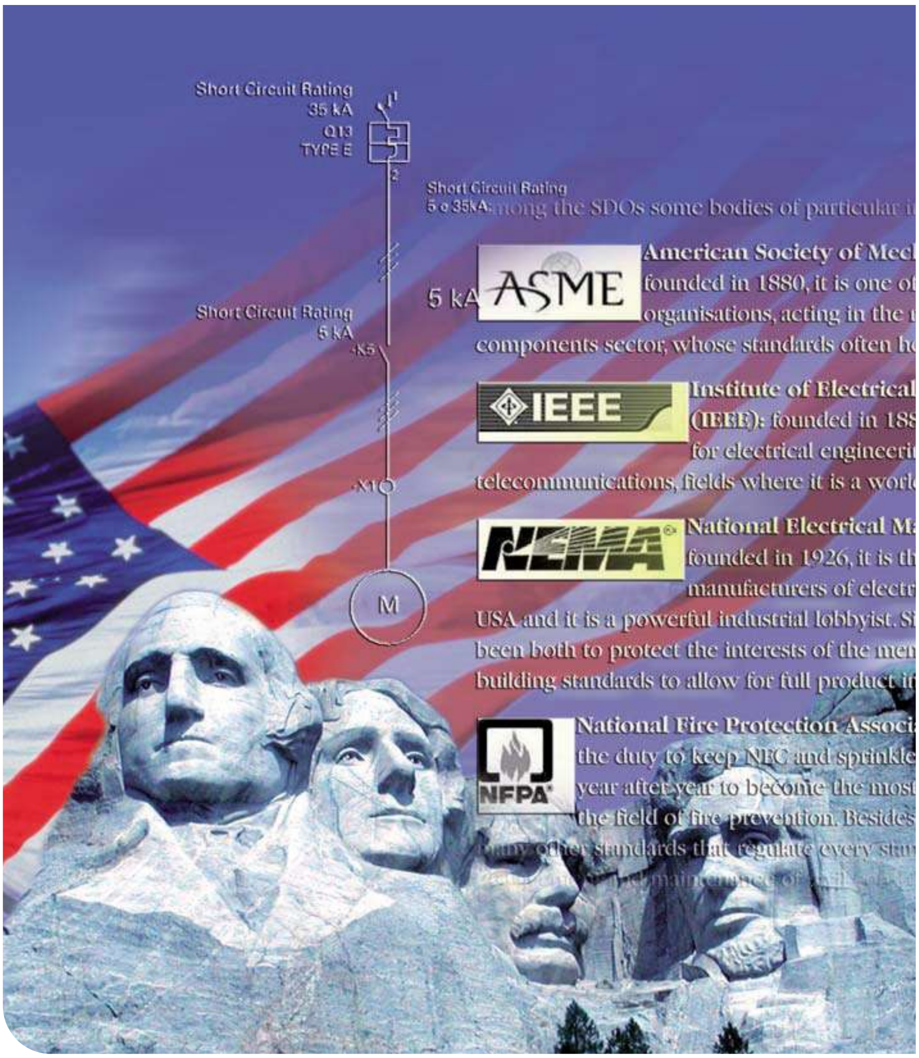

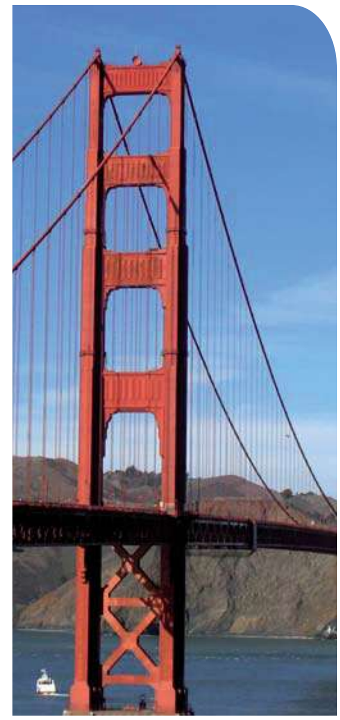

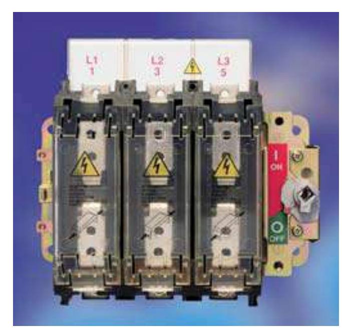

INTRODUCTION TO NORTH AMERICAN STANDARDS

AN APPLICATION GUIDE FOR ELECTRICAL CONTROL CIRCUITS IN THE FIELD OF INDUSTRIAL AUTOMATION

ALLEN-BRADLEY • ROCKWELL SOFTWARE

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In the European Union

The national technical regulations are subject to provisions of articles 28 and 30 of the treaty establishing the European Community (the EU treaty) that prohibit quantitative restrictions and all other measures having equivalent effect.

With the Council's decision on a new strategy aiming at technical harmonisation and standardisation, a new technical regulation has been established to set the following principles:

- Legislative harmonisation is limited to the essential requirements that products imported to the Community market should respect to circulate freely within the Community
- The product technical specifications that meet the **essential requirements** set in the directives are defined as **harmonised standards**
- The application of harmonised standards or other kinds are voluntary and the manufacturer can always apply other technical specifications to meet the foreseen requirements
- The products manufactured following the harmonised standards are considered as complying to the corresponding essential requirements
- The provisions in the directives of the new approach prevail over any other equivalent national provision
- The member states have the obligation to incorporate the directives of the new approach in their national law
- Any national legislative, regulatory or administrative provisions adopted must be reported to the European Commission

In The United States

Regulations for the United States are contained in the **"Code of Federal Regulations"** (CFR) which is the Code of the standards issued by the Executive and the Federal Agencies. The CFR is divided into titles (for example, title 29 - Labor, is about all regulations related to employment). Every title is sub-divided into chapters (chapter XVII of title 29 is about occupational health and safety standards, divided by sectors).

It is important to highlight how the CFR details health and safety requirements, unlike the European system in which this role is subjected to specific standards.

Regulations on electrical equipment is contained in title 29, chapter XVII, subpart S (1910.3).

Besides CFR, the **National Electrical Code** (NEC) is the reference standard for electrical systems in the United States.

1.2 Market control systems and Control bodies

The control structure in the European Union is carried through the Production Ministry (or Industrial and Commerce Ministries) and from the local organisations (in Italy, for example, the ASL or SPISAL Services of Prevention and Protection).

In EU countries, manufacturers have had to build machinery and/or components observing the Directives in force in their specific sector, and referring to the harmonised standards.

The Declaration of Conformity, issued by the manufacturer, and the CE conformity mark, are proofs of compliance with the Directives and they are not subject to verification by third bodies unless in particular cases (some categories of dangerous machinery, lifting equipment, PED pressurised containers, etc.).

In Europe the intervention of authorities generally occurs after an accident, as a preventive assessment or as a result of an external evidence signalling presumed non conformity.

Procedures foreseen in the safeguard clauses of the relevant directives are triggered after these controls.

Supervision in the United States market is in the hands, first, of the OSHA **(Occupational Safety and Health Administration)** and the NIOSH **(National Institute for Occupational Safety and Health).**

The Occupational Safety and Health Act of 1970 established both NIOSH and OSHA. OSHA belongs to the Department of Labor and is in charge of developing and enforcing safety and health standards in working environments by issuing accurate regulations and standards. OSHA plays another extremely important role in safety as it is the only organisation authorised to accredit a **National Recognised Testing Laboratory (NRTL),** that is laboratories authorised to certify component and material conformity according to standards in force.

On the other hand, NIOSH belongs to the Department of Health and Human Services and it is an agency set up to ensure adequate labour conditions, through research, information and training of workers.

The local (county) supervision and checks are managed by the inspector with jurisdiction known as **AHJ (Authority Having Jurisdiction).**

Here is a brief outline of the Canadian supervisory structure derived from the mix between the American counties (especially in the Western states) and the European governmental structure. There are "municipalities" that managed their own local territory, and on the other hand, there are the "agencies" working within only one state (for instance, the **Electrical Safety Authority, ESA,** in the state of Ontario). Afterwards each single Labour ministry accredits the inspection bodies.

Canadian Centre for Occupational Health and Safety (CCHOS): it is the Canadian equivalent of the American OSHA. From 1978 the role of this Centre is to provide occupational safety guidelines for factories and working places, which are valid throughout the Canadian federation. Like for OSHA, the rules defined by CCOHS can be modified by the Labour ministry of each state provided it enhances safety.

1.3 The role of the AHJ

The North American approach is completely different from the European one.

Self-certification is not considered satisfactory and the safety of a plant or machinery is based on the premise that everything has been previously controlled and certified.

The guidelines compiled by OSHA are taken as reference by AHJs to settle their own safety rules for workers; AHJs can modify the OSHA prescriptions only for the sake of safety.

In particular, Annex G, article 80.13 of the National Electrical Code reads: **"The Authority Having Jurisdiction shall be permitted to render interpretations of this Code in order to provide clarifications to its requirements."**

This affirmation in the NEC is fundamental as it enacts the possibility for an AHJ to interpret the NEC and accordingly approve or not, in the last resort, some machinery or any electrical equipment.

The inspection by Supervisory authorities consists of:

- checking that the design and manufacture are based on the rules and legislation in force
- checking that the components used are certified by an accredited NRTL laboratory

The responsibility of these bodies is to check conformity with the safety standards in force under operating conditions (industrial plants or machinery). For example, for electrical systems this inspection in done by referring to the NEC installation codes.

1.4 Obligations of machinery manufacturers

The obligations for machinery manufacturers who try to import their products into the European Economic Space (EES) or the North American market can be summarized as follows:

- to enter the EES: obligation to follow the reference directives for the product, to carry out an analysis of the machinery risks in order to draw up the Technical Document, obligation to bear the CE marking, without having the machinery certified by third body (except for foreseen cases)

- to import into North America: compliance with federal laws, obligation to attest component conformity and in some cases, to submit the product to authorised inspectors.

2. Historical evolution of the North American regulations

The historical reasons that justify the differences described are found not only in the cultural diversity but also in the communication difficulty between two worlds, at least up to the end of the XIX century.

The oceanic distances and the different background philosophy have emphasised the differences up to the recent times; that is why two different approaches to solve the same safety problem developed at each side of the ocean.

The brief historical account that follows wants to briefly explain how the structure of the different standards and regulations for electrical system have developed to be shaped as we know them today.

In the United States Thomas Alva Edison patents the first incandescent light bulb (1879) and, in 1882 investing the earnings of his patent the best way in the telegraph, The Edison Electric Light Company is established and a direct-current power plant is built in New York. Electric current, whether direct or alternating, propagates really fast and so does the increase of the fires due to electrical causes and the relevant insurance refunds.

In 1893 during the Universal Exhibition in Chicago, the Palace of Electricity represents the first time electric energy imposes over any other forms of energy, and also the time when American insurance companies accept to compromise only after carrying out thorough inspections of installations.

Under the pressure exerted by insurance companies, and also due to purely economic reasons in first place, five different installation codes are developed. All attention is mainly focused on fires that are an unavoidable consequence of overloads and short-circuits in buildings mainly characterised by the use of wood.

A feature common to all electrical code is the requirement to use safe electrical components, but the different provisions make it impossible for manufacturers to produce a common product.

In 1897 the main organisations around the country defined a sole installation code valid for the whole federation, the **National Electrical Code (NEC)** which was immediately adopted by all the main organisations of fire prevention and protection, and above all, by insurance companies.

At the same time as the NEC, the installation codes for automatic sprinkling systems were drawn up and the organisation in charge of updating the technical specifications of both codes (every three years) was set up: the **National Fire Protection Association (NFPA).**

Canada had a different development from the USA, as it was British empire colony and therefore theoretically subject to the same rules in force in the United Kingdom. In fact, in 1917 Canada creates an independent normative body, the Canadian Engineering Standards Association (CESA).

The CESA begins activities in 1920 and immediately expands its influence over the electric sector publishing the first **Canadian Electrical Code (CEC)** in 1927, inspired in the American NEC.

In 1940 the CESA enters the field of product certification and changes its name to **Canadian Standards Association (CSA).**

The history of the European standards has completely different origins, deprived in fact of the pressure of the insurance companies.

In Europe the standards bodies develop as academic associations: in 1901 **British Standards (BS)** was established, in 1906, the **International Electrotechnical Commission (IEC)** and in 1909 the **Comitato Elettrotecnico Italiano (CEI)** were set up.

Harmonised standards for the electrotechnical sector are issued by the **European Committee for Electrotechnical Standardisation (CENELEC),** adopted and translated by the national standards bodies. EN standards are often standards issued by the International Electrotechnical Commission (IEC) with some differences.

Harmonised standards for other sectors are issued by the **European Committee Standardisation (CEN)** and adopted and translated by the national standards bodies. EN standards are often standards issued by the **International Organisation for Standardisation (ISO)** with some differences.

In USA the standard process is much more complex as it is "voluntary" type of system; firms, technicians and insurance companies of each sector have collaborated to produce their own reference standards giving birth to a high number of standard organisations.

The main problem in a voluntary standard system is co-ordination among the different standard bodies and this has brought about the settlement of **AESC (American Engineering Standards Committee)** in 1918, known as **American National Standard Institute (ANSI)** since 1969. This organisation, born from the collaboration of the most important bodies as IEEE, ASME, ASTM and others, imposed itself immediately to federal level and along the years it has incorporated and gathered all similar bodies and became the reference for international standard associations.

Since 1931 ANSI has participated in IEC works through the **U.S. National Committee (USNC)** and in 1946 became one of ISO founder members.

ANSI accredits sector standards bodies and co-ordinates and regulates the creation of standards through the regulations called "ANSI Essential Requirements". At present over 200 standards bodies are accredited, called **Standards Developing Organisations (SDO)** and there are over 10,000 recognised standards (if public and private bodies not accredited by ANSI should be included, other 700 organisations could be added to reach a total of around 93,000 standards).

Among the SDOs some bodies of particular importance can be individualised:

American Society of Mechanical Engineers (ASME): founded in 1880, it is one of the main American engineering organisations, acting in the mechanical and pressurised components sector, whose standards often hold international value

Institute of Electrical and Electronics Engineers (IEEE): founded in 1884, it is the standard reference body for electrical engineering (medium voltage), electronics and telecommunications, fields where it is a world leader

National Electrical Manufacturers Association (NEMA): founded in 1926, it is the organisation that gathers manufacturers of electrical and electronic materials in the USA and it is a powerful industrial lobbyist. Since it was born, the mission has been both to protect the interests of the member firms and to set up common building standards to allow for full product interchangeability

National Fire Protection Association (NFPA): founded in 1896 with the duty to keep NEC and sprinkler standards updated, it has grown year after year to become the most important American organisation in the field of fire prevention. Besides the original standards there are many other standards that regulate every standard regarding building, management and maintenance of civil constructions and industrial plants, to provide safety against fire. NFPA is also active in the educational field and, with the **NFPA79** standard on **"Industrial Control Machinery",** in the field of machinery safety

In Canada the structure is similar to that in the United States, but with some differences related to its prolonged permanence within the British domination and later on, the European dominance. Every single Canadian state accredits the standards bodies authorised within its territory through the labour ministry and it recognises the standards.

The co-ordination among the several ministries is guaranteed by the **Standards Council of Canada (SCC),** founded in 1964 to solve commercial and safety problems arising from the lack of standardisation. SCC is also the reference for the ISO and IEC international bodies. Among its various activities, SCC also is devoted to:

- Accredit of standards bodies, SDOs and recognise their standards like ANSI
- Accredit **National Recognised Testing Laboratory (NRTL),** that is, laboratories authorised to certify the component and materials conformity to the standards in force
- Accredit inspection bodies

Also in Canada there is an active organisation that gathers electric and electrical material manufacturers, **Electrical Equipment Manufacturers Advisory Council (EEMAC),** whose mission is similar to NEMA's.

Finally it is important to mention the **Council for Harmonization of Electrotechnical Standardization of North America (CANENA),** a body that deals with harmonising standards within the NAFTA countries

2.1 Certifying authorities

The principal laboratories that certify products are:

Underwriters Laboratory Inc. (UL); founded in 1894 as a branch of the fire brigade laboratory, is the main USA laboratory and one of the renowned certifying organisations in the globe; it is an independent non profit organisation that carries out tests and issues product safety certifications. In 2003 more than 19 million products with the UL mark were manufactured.

As a standards body accredited by ANSI, it sets the requirements the products must comply with and defines the tests to control their conformity. Underwriters Laboratory is recognised as a leader in the field of safety tests and its standards are also generally used even by other test laboratories.

Canadian Standard Association (CSA): is the principal standards organisation and certifying authority of Canadian products and plays a similar role in Canada as that of the UL in the USA.

It is accredited by SCC as a laboratory and as standard organisation, and besides publishing and updating the CEC, it issues manufacturing standards tests for products.

There are 18 laboratories accredited by OSHA in the USA and 26 by SCC in Canada. Some laboratories are recognised in both countries: **Entela, Intertek Testing** (known also as **ETL Semko), MET Laboratories, TUV** (in several versions).

Organisations currently recognised by OSHA as NRTL:

(the list may change; please refer to OSHA web site:
http://www.osha.gov/dfs/otpcal/nrtl/index.html

Applied Research Laboratories, Inc. (ARL)

Canadian Standards Association (CSA) (also known as CSA International)

Communication Certification Laboratory, Inc. CCCL)

Curtis-Straus LLC (CSL)

Electrical Reliability Services, Inc. (ERS) (also know as Conformity Services and formally as Electro-Test, Inc. (ETI))

Entela, Inc. (ENT)

FM Global Technologies LLC (FM) (also know as FM Approvals and formally as Factory Mutual Research Corporation)

Intertek Testing Services NA., Inc. (ITSNA) (formally ETL)

MET Laboratories. Inc. (MET)

NSF International (NSF)

National Technical Systems. Inc. (NTS) SGS

U.S.Testing Company, Inc. (SGSUS) (formally UST-CA)

Southwest Research Institute (SWRI)

TUV America, Inc. (TUVAM)

TUV Product Services GmbH (TUVPSG)

TUV Rheinland of North America, Inc. CTUV)

Underwriters Laboratories Inc. (UL)

Wyle Laboratories, Inc. (WL)

3. Main reference texts

The National Electrical Code, already mentioned, sets a series of manufacture and safety requirements for the installation of components and electrical equipment. It is defined as an "open and consensus-based code" and it ensures that every new or revised requirement reflects the current progress of technology.

The NEC also covers installations in dangerous environments (explosive atmosphere). Establishes a series of "rules":

- mandatory rules (actions specifically required or prohibited)
- permissive rules (permitted but not required actions)
- explanatory material (references to other standards, informative notes)

Normally the NEC rules are more restrictive than OSHA rules, but the opposite may also be true.

Particularly OSHA is more restrictive in the prescriptions for components admitted for use in the electrical plants/equipment.

OSHA regulations only permit the use of components that have been tested and certified by an NRTL test laboratory.

Meanwhile NEC foresees the use of components that are considered still suitable for use.

In fact this difference is annulled by the habit of AHJs to accept only certified components, admitting non-listed components only in a few and justified cases.

In both texts there is a clear reference to the fact that components have to be installed in full conformity with the use conditions foreseen in the certification.

In some specific sectors an important reference is the **"Electrical Standard for Industrial Machinery" (NFPA 79).** It is a standard that transfers the **EN 60204-1** to the American industrial world without altering the sections related to machine operation (e.g. human-machine interface, control circuits, etc.) but replacing the paragraphs related to electrical system layout with the similar sections taken from NEC.

Industrial Machinery means:

a) **metal working machines tools,** inlcuding also metal cutting and moulding machinery

b) **plastic processing machinery,** including thermoplastic and thermosetting moulding, extrusion, blowing, specialised jobs and size reduction

c) **woodwork machines,** including of woodwork machines, laminators and panel saws

d) **assembly machinery**

e) **material handling machinery,** including industrial robots and transfers

f) **trial and testing machines,** including measuring machinery using co-ordinates and "in-process" measuring devices

Specific installation standards can be added to the federal rules such as those for machine tool equipments, **UL508A "Industrial Control Panel".**

UL508A is divided into a section containing rules applicable to all equipments to which other sections are added, that include rules for some specific machinery types (Industrial Machinery, which includes design parameters defined in NFPA79, as well as lifts, conditioners, sea environment and others).

In Canada:

Every state issues its own safety at labour rules (for interstate workers and other specific sectors, it is the "Canada's occupational safety and health" - CANOSH) and the CCOHS plays the role of guiding and co-ordination body.

For the electric safety, the local installation code is always taken as reference, which derives from the Canadian Electrical CODE **(CEC)** published by CSA. Therefore, the CEC is the main reference to design the equipment.

The CEC, also known as CSA 22.1, a specific standard for "Industrial Control Panel" **(CSA 22.2 #14)** is added to the CEC, also known as CSA 22.1. The standard contains applicable additional prescriptions for the sector of the automation panels.

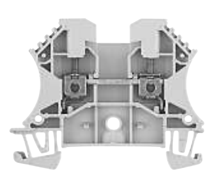
3.1 Component certification

A component certification is evident by applying a mark by the certifying laboratory. Underwriters Laboratory for instance affixes the UL "label", while the Canadian Standard Association affixes the CSA mark. It is worth noticing that Underwriters Laboratory issues two different types of approvals, "Listed (UL)" and "Recognised (UR)", each of which is characterised by a specific mark, UL and UR respectively.

The difference lies in the field of application of the marked product:

100-C

UL listed: it deals with components defined as "complete devices", or finished products, with an autonomous function. They are marked with the name and the logo of the manufacturer, with all the data concerning tests and the UL mark. These components do not require specifically trained personnel for installation (the typical example is a contactor, circuit breaker, etc.) These components are managed by the manufacturer, but are verified by the UL Inspector according to product quantities.



1492-J

UL Recognised: This mark is used for components that do not have their own function but are assembled with other parts and components, a UL Recognition mark is applied on the finished product. The UL-recognized components are marked only with the name and the logo of the producer and the type. These components require qualified personnel for their installation, in compliance with the prescriptions and the use limits set by the manufacturer (conditions of acceptability indicated in the files or UL certification report).

The Recognised UR mark is exclusively issued for the immediate identification of the product in the American market and has not meaning in other markets.

To increase product turnover and to simplify the appraisal procedures, the two principal UL and CSA organisations and all NRTL laboratories have reached an agreement of mutual acceptance of certification tests in 1998.

This recognition has resulted in the introduction of unified marks.

Where the suffix refers to Canada and the United States respectively.

Before this unification products will have to be tested and recognised individually by Canada and the United States.

4. Machinery and plant certification in the USA

Besides restrictions foreseen by the local laws, the OSHA and CFR 29 for some particular machinery types, there is no obligation to certify through a third party the plant or machinery at the moment of installation. On the other hand to get the certification of a laboratory is possible only through a verification procedure and a specific standard.

In specific cases of electrical equipment of machinery for the USA, the reference standards are represented by the NEC 2005 installation code, art 409 "industrial machinery", and the voluntary **UL 508-A "Industrial Control Panel"** standard.

For the Canadian market the references to obtain a certification are the CEC 22-2 installation code, part 1 and CSA 22-2 N°14s "Industrial Control Panel" standard.

For the industrial machinery such as woodworking machine tools, machinery for plastics and metal, some additional requirements applied are defined in the NFPA 79 Electrical Standard for Industrial Machinery.

1. Switching and protection of the electrical equipment

1.1 The different types of circuit

The North American standards divide the power circuits into two parts, better defined as:

- Feeder Circuit
- Branch Circuits

This distinction, neglected in the European environment is, on the other hand basic in North America for the choice, sizing and wiring of components inside electrical equipment.

The definition of feeder and branch can be found in both the NEC (National Electrical Code) and in the UL 508A.

National Electrical Code (art. 100 Part 1) and in the Canadian Electrical Code (section 0):

Feeder: all circuit conductors between the service equipment, the source of a separately derived system or other power supply source and the final branch overcurrent device.

Branch Circuit: the circuit conductors between the final overcurrent device protecting the circuit and the outlets.

An example of ***feeders*** and ***branch circuits***

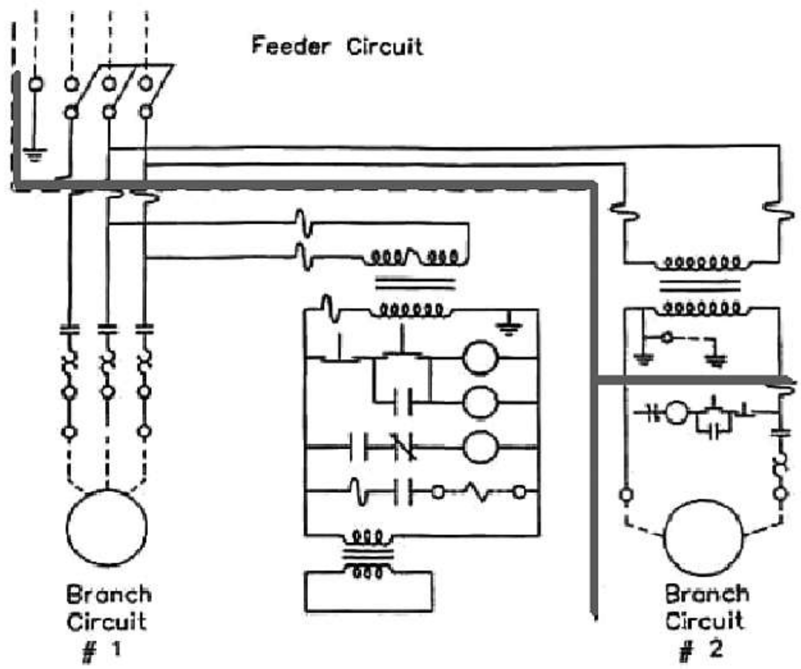


Figure: Feeder circuit

Feeder: all the conductors and the circuits up line from the supply side of the branch circuit overcurrent protective device.

BCPD: Overload protection device (e.g. circuit breaker, fuses).

Branch Circuit: the conductors and the components down line from the last over current protective device and the load Branch Circuit #1 Branch Circuit #2

In branch # 1 the branch circuit begins at the fuse connection power blocks *(branch circuit* protection). In the case of circuit # 2 the transformer and the relative protection at the primary should be considered part of the feeder, therefore in cases of transformers and/or autotransformers, the Branch Circuit always begins at the secondary of the transformer/autotransformer.

1.2 Power circuits and control circuits

The circuits inside electrical equipment are sub-divided between:

- Power circuits
- Command and control circuits (remote control circuits)

Command and control circuits are considered the circuits that power and control loads such as:

a) A pilot light shall comply with the Standard for Industrial Control Equipment, UL 508, and a miscellaneous lamp holder shall comply with the Standard for Edison-Base Lampholders, UL 496;

b) An electrically-operated valve shall comply with the Standard for Electrically Operated Valves, UL 429;

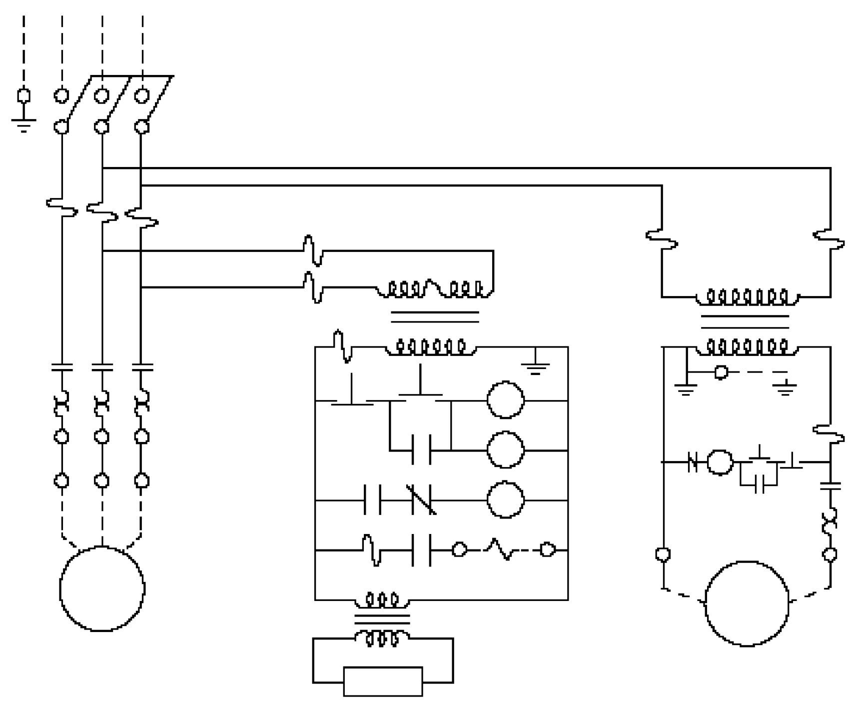
c) A solenoid shall be evaluated for the intended use;

d) A time-indicating or time-recording device, including an hourmeter, or a synchronous motor shall comply with the Standard for Time-Indicating and -Recording Appliances, UL 863;

e) An electrically operated counter shall comply with the Standard for Time-Indicating and -Recording Appliances, UL 863;

f) An audible signal appliance, including a horn, bell, or buzzer, shall comply with the Standard for Audible Signal Appliances, UL 464; and

g) A coil or input circuit to another control circuit switching device or to a load controller shall comply with other component requirements in this standard.

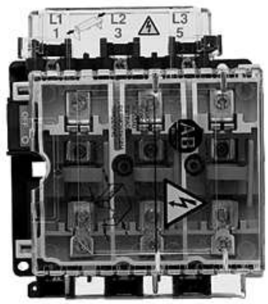


All others are considered loads and thus power circuits regardless of the voltage and the load absorption.

In North America the distinction is generally made on the basis of the final load function (motor, inverter, lights, resistors etc…) regardless of the power voltage and the current e.g. a stepper motor powered at 24 Vdc with a load current of 200mA is considered power, a solenoid valve at 24 Vdc with a load current of 2 Ampere is command and control.

Note: lights and fans for electrical cabinets are considered command and control circuits. If installed in the field (outside the electrical cabinet) they shall however be considered power circuits.

2. Disconnecting means



194R

1494V

The main disconnecting means is a necessary part of all electrical equipment but can be provided by the final user (unlike the provisions of European standards). In this case it is necessary to clearly specify the characteristics of the device in the attached documentation.

In this section, the devices suitable for switching and their sizing independently of their nature will be analyzed (switch or circuit breaker).

It is possible to use the devices suitable for disconnecting to the function of overload protection of electrical equipment.

2.1 Sizing the switch in accordance to UL 508

First of all it is necessary to distinguish between switch and circuit breaker.

Inverse-time or instantaneous-trip circuit breaker UL489 "Molded-Case Circuit Breakers, Molded-Case Switches and Circuit Breaker Enclosures)

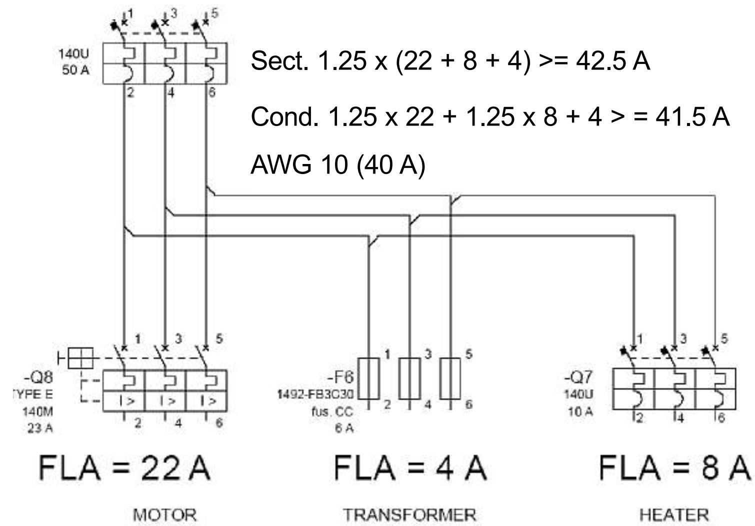
The total current (obtained by adding the FLA and the rated currents of all the branch circuits) should not be more than 80% the size of the switch. It may be more useful to express the same rule backwards: the size of the switch should not be less than 125% of the total current.

EXAMPLE

Motor 7.5HP, 230V, 3ph
Table 50.1 > FLA = 22A

The circuit breaker shall have a size of
at least 1.25 x (22 + 8+ 4) > = 42.5A

For example a **140U-H2C3-C50** can be used



Disconnect switch (or switch with fuses) (UL 489 or UL 98, *"Enclosed and Dead-Front Switches"*

Sizing follows different rules according to the type of load.

a) one or more loads, no motor: the size in current of the switch should not be less than 115% of the total current (sum of the rated currents of all the branch circuits).

b) a single motor: the power size (hp) of the switch should be shown in current (using table 50.1 of UL 508A): this value obtained shall not be less than 115% of the FLA (also obtained from tab. 50.1)

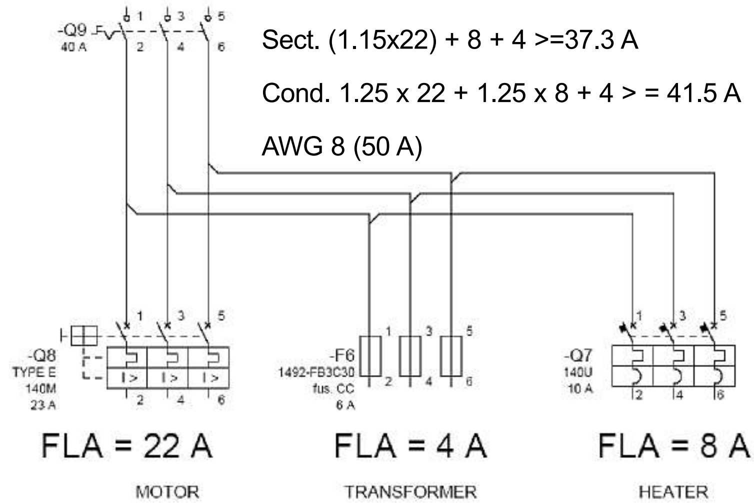
c) one or more motors and other loads: the power size (hp) of the switch shall be shown in current (using tab.50.1 of UL 508A): this value shall not be less than 115% of the FLAs of all the motors plus the rated currents of all the other loads.

EXAMPLE

230V Three-phase system

The current for the sizing of the switch is: (1.15x22) A + 4 A + 8 A = 37.3 A

Now it is necessary to choose a switch with a size in power such that the current received as in table 50.1 is above 37.3A: at 230V a switch of 15 hp (corresponding with 42A) is required.



The suitable IEC/UL/CSA component is a **194R-NN060P3** (CCN, WJAZ, conforming to UL 489) while in a NEMA start a **1494F-N60** (CCN, WHTY, conforming to UL 98) is used, both with power rating equal to 15 hp (230V).

2.2 Sizing according to the CEC for the Canadian market

The sizing regulations are simplified because no distinction is made between circuit breaker and switches and only the following rules are applied:

- size in current of the device should not be less than 115% of the current of the largest motor plus the sum of all the FLAs of the other motors and all the rated currents of the various loads from the motors.
- The power size of the device, if indicated should not be less than the power of the largest motor.

2.3 Sizing in accordance with the NEC

The sizing of the switching device in the NEC requires the verification of two different conditions, depending on the use of a power characterized component (switch: hp rating) or characterized in current (circuit breaker: rating in A): however some exceptions are applied. No other distinction is made between circuit breaker and switches.

- Sizing in current: the size in current of the device should not be lower than 115% of the total current, obtained as the sum of the FLA of all the other loads.
- Sizing in power: two values are calculated, one relative to the sum of the FLAs (current at full load, tab 430.250 of NEC or tab. 50.1 of UL 508A) and one to the sum of the LRA (current with the rotor blocked table 430.251(B) of NEC) of all the motors. The nominal currents of all the other loads (not motor) should be

added to both values.The two values obtained are considered FLA and LRA of a single virtual motor representing the full machine, the power of which (in HP) can be obtained from the tables for example tab 50.1 of UL 508A).

The switching device should have an hp size above that of the virtual motor (remember that the LRA of the switch is set at 6 times the FLA exactly like the conductors).

In the case of components characterized both in power and in current both sizing are applied: if however the component is specially approved for motor switching (e.g. manual motor controller) the sizing in current is not necessary.

2.4 Conforming components that can be used for disconnecting means

The devices that can be used for switching and protection of the electrical equipment of the machines are:

- Circuit breaker conforming with UL 489
- Switches with or without fuse UL 98.

140U

2.5 Components that cannot be used for disconnecting means

- Circuit breaker conforming with UL 508 certified as Manual Motor Controllers
- Switches with or without fuses conforming with UL 508A certified as Manual Motor Controllers

The limitation of these components is connected with the location of the command and control in the electrical equipment. In particular the use and installation of these components is not permitted in feeder circuits in North America.

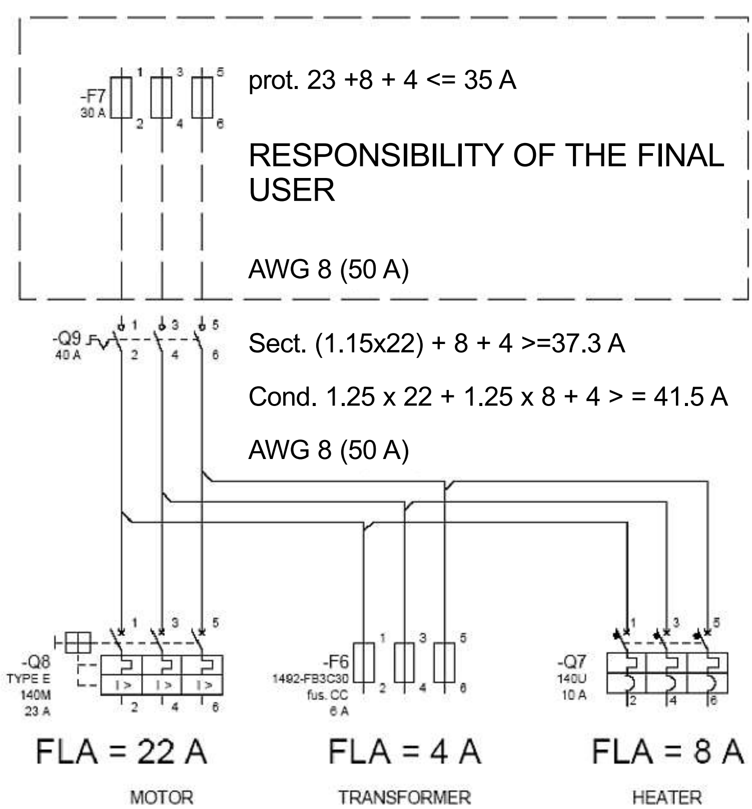
2.6 Components accepted with restrictions

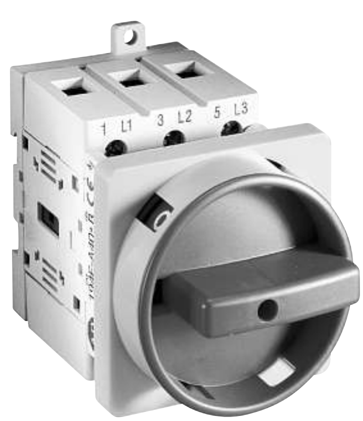
The UL 508A standard allows "Industrial Control Equipment" called "Manual Motor Controllers" certified and marked as "Suitable as Motor Disconnect" as UL 508 switch device.

These switches should generally be protected by fuses against over currents. This protection however may be provided in the field.

In the machine documentation the installation of an overcurrent protection, fuses or boxed circuit breaker should however be explicitly required by the final user.

The manufacturer of the machine should indicate both the type and size of the protection (calculated as per the following paragraph) and the cross-section of the power conductors of the panel to be installed in the field (see example of wiring diagram).



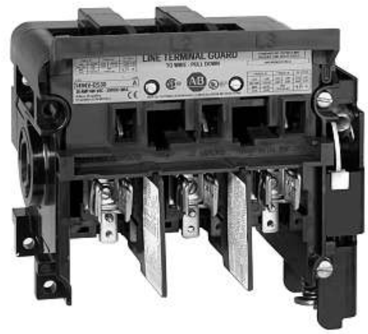


194E switch

3 Feeder overcurrent protection

140U


1489



1494V


1491


140F

The devices protecting the panel from over currents are explicitly required only in the case of Industrial Machinery[1]) by NFPA 79 (and relative section of the UL 508A), but its presence is also provided for in NEC and CEC in which sizing rules are given.

Obviously the protection of the lines powering the equipment is not the responsibility of the machine manufacturer.

It is noted that in the case of circuit breaker (devices suitable for switching and protecting) calculations must be made for sizing both for overcurrent protection and for disconnection means.

The sizing of the overcurrent protection follows the same rules in all the standard texts.The size/calibration should not be more than one of the following two values:

a) the protection size/calibration of biggest branch (BCP) plus the rated current (FLA) of all the other motors plus the rated currents of all the other loads (for machinery, this is 125% of the largest motor – from table 50.1, +125% of all heater loads; + FLA – from table 50.1 of all other motors, + FLA of all other loads;
or

b) the capacity of the feeder conductor (conductors or bars down line of the overcurrent protection)[2])

It often happens, especially when using automatic switches, that the calculation provided for in case a) gives results that are incompatible with the sizing of the switching device: in the case of circuit breaker this makes an oversizing of the feeder conductor obligatory to enter into case b)

This solution should be applied, though not required by the CEC for equipment destined for Canada as well: in fact value b) can be modified with a simple over sizing while the modification of value a) often implies a complete revision of the panel.

[1]) The following are considered industrial machinery: metal working including machinery for deformation or cutting: wood; plastic, assembly machines; robots, transfer and test machinery.

[2]) The CEC for Canada does not provide for case b) but only the value calculated in a).

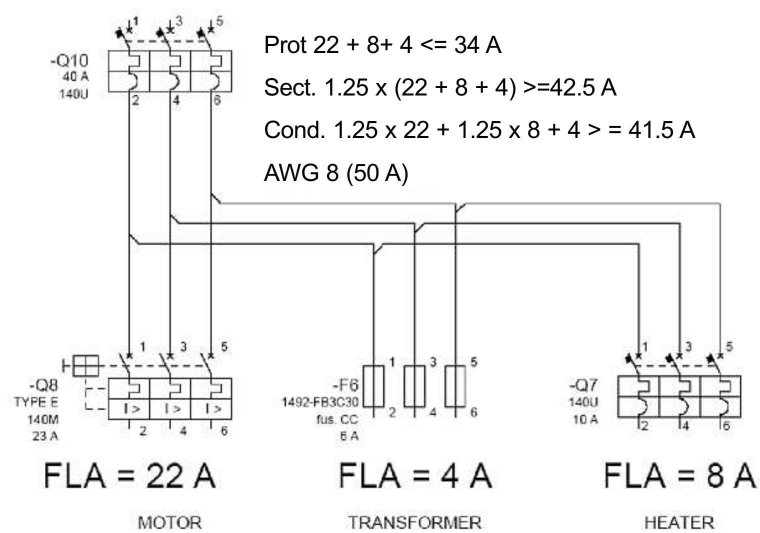
EXAMPLE

As in the previous example a feeder protection and switch with circuit breaker (series 140U) is taken up again.

The switching function requires a size of no less than 40 A but the calculation of the value a) as overcurrent protection requires the size not to be more than:

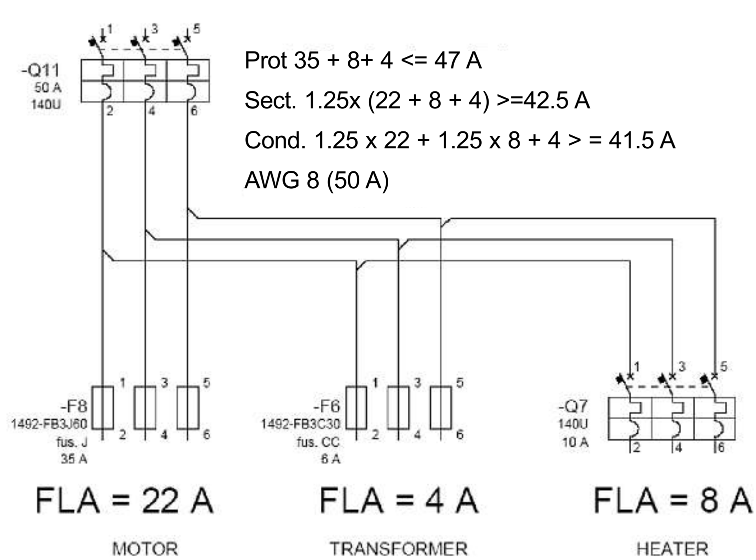
22 + 8 + 4 = 34 A

The incompatibility of the design data is clear



Three solutions are proposed

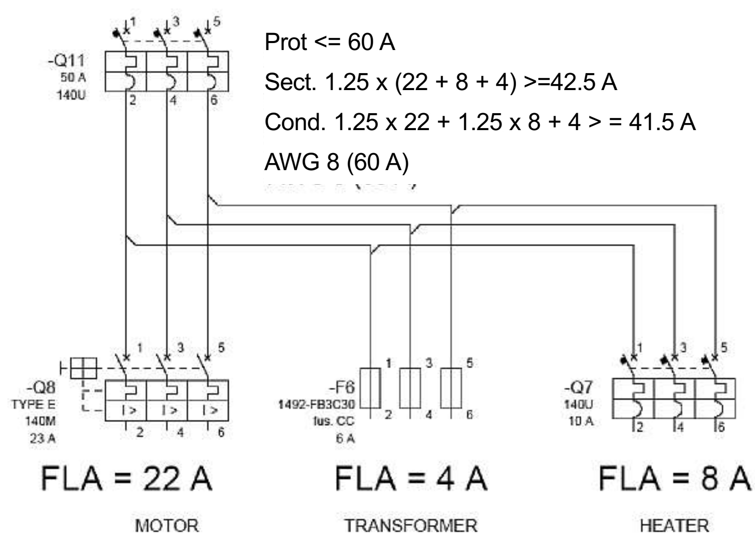
1. Foregoing the protection function and sizing the **140U** only as a switch. In this case it will be necessary to install another device with a size no greater than 35A to perform the function of the protection;
2. Modifying the equipment to raise value a) from 35 to a value greater than 40 A



For example the motor (FLA = 22 A) can be protected with time delay fuses rather than an "Type E" combination motor controller. In this case the calculation of the BCP would lead to a value of 35 A (for the calculation of the size please refer to publication 3 "Branch Circuit" with J type 35 A fuses in the relative fuse holder **1492 – FBJ60.** The calculation of value a) now could be 35 + 8 + 4 = 47 A.

There is no longer incompatibility and the circuit breaker should have a size between 40 and 47 A: the standard size suitable is 45 A and a **140U-H2C3-C45** can be installed.

3. Install a feeder conductor with a capacity of more than 40 A. In this particular case a AWG 10 bearing 40 A has already been anticipated, therefore the same **140U-H2C3-C40** as previously defined can be used.



If an AWG 8 with a 60A capacity had been used it would have been possible to use any 140 U with a size of between 40 A and 60 A, for example a **140U-H2C3-C50.**

For the best use of the switches with fuses it is sufficient to choose the fuse size compatible with the calculations made above.

3.1 How to protect the electrical equipment from overcurrents (feeder protection)

If we install a switch in the electrical equipment, the feeder circuit is extended as far as the first branch protection (BCP red line in the figure);

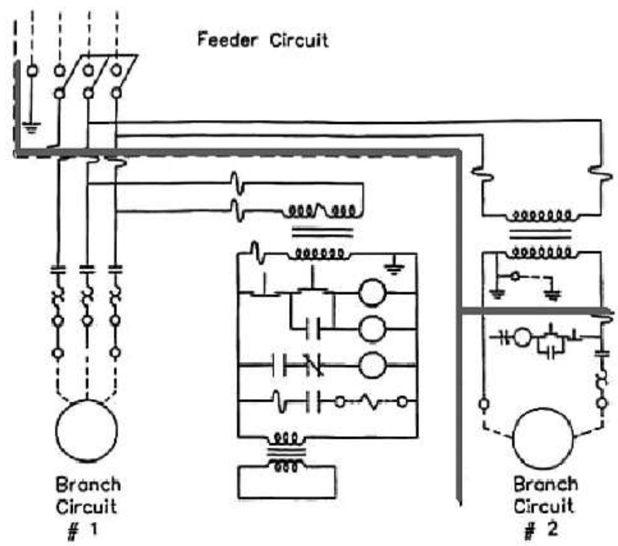
What are the components that could be employed in the circuit feeder?

- UL 489 circuit breaker
- UL 248 fuses

The combination motor controllers are UL 508 certified and cannot be used.

The designer is limited in the choice and use of some components because the standard provides that the starts of the motor be realized exclusively with UL 248 fuses or UL 489 circuit breaker contactor and thermal relay.

On the other hand, if disconnecting devices are planned with the feeder protection function, there are no restrictions in the use of the components in the electrical equipment.



Feeder: all the conductors and the circuits up line from the last overcurrent protection device of a branch (branch circuit).

BCPD: Overload protective device (e.g. circuit breaker fuses).

BCPD: Overload protective device (e.g. circuit breaker fuses).

Branch Circuit: the conductors and the components down line from the last over current protection device and the load Branch Circuit #1 Branch Circuit #2

4. Internal wire

The internal distribution of a industrial control panel is normally made with a line of conductors that power the distribution terminal strip from which the conductors with a smaller cross-section are derived and that power the protection devices of the individual branch circuits. Alternatively, a bar system by which the conductors are derived directly at the BCPs. in the case of high currents can be used

It is necessary to distinguish between:

- *"Feeder conductors":* the conductors/bars or larger cross sections:
- *"Tap conductors":* any derivations of smaller cross sections that power the branch circuits.

4.1 Distribution mounts, Power Block

For panels of large capacities it is sometimes necessary to make distribution systems to make it possible to power several users with different and/or smaller cross-sections.

All the distribution "mounts" or "commercial" bars used **should** be NRTL approved because they are particularly critical components in the case of short circuit.

In fact power blocks are very common in North America; they are certified for the electrical distribution inside electrical industrial control panels.

1492-PD

In case it is not possible to use a Power Block, a system of bus bars can be constructed

Note: it is not easy to calculate the capacity of the system because short circuit tests have not been conducted but the reference values of data supplied by the insulation and bus bar section manufacturers can be extrapolated. With reference for the distance in the air and surface reference can be made to table 10.2 of UL 508A.

Voltage Involved	Minimum spacing, inch (mm)		
	Between live parts of opposite polarity		Between life parts and grounded metal parts, through air and over surface
	Through air	Over Surface	
125 or less	$^{1}/_{2}$ (12.7)	$^{3}/_{4}$ (19.1)	$^{1}/_{2}$ (12.7)
126 - 250	$^{3}/_{4}$ (19.1)	1 – $^{1}/_{4}$ (31.8)	$^{1}/_{2}$ (12.7)
251 - 600	1 (25.4)	2 (50.8)	1 (25.4)
NOTE – An isolated dead metal part, such as a screw head or a washer, interposed between un insulated parts of opposite polarity or between an un insulated live part and grounded dead metal is evaluated as reducing the spacing by an amount equal to the dimension of the interposed part along the path of measurement.			

Table 10.2 of UL508A provides the minimum spacing also for the certified bus bar systems.

4.2 Sizing of the Feeding Conductor

In UL 508 A and CEC the current is determined according to the single loads, such as:

125% rated current of the largest motor
added to
100% of rated currents of all the remaining loads

where the rated current of the motors is the FLA in the USA, the rating plate value in Canada.

In the case of resistive loads, the CEC introduces a modification in the calculation that is also present in NFPA 79 for Industrial Machinery. **From the point of view of a unified sizing it is recommended that this calculation method be always adopted:**

125% rated current of largest motor
added to
125% of rated current of resistive loads (heaters)
added to
100% of the rated currents of all the remaining loads

The capacity of the internal conductors should not be lower than the calculated load. Table 28.1 of the UL 508 A standard is used. It contains the reference capacities for isolated thermoplastic conductors with a functioning temperature at 90° C and in this the installation and temperature rating is considered. Th**is table can be taken as the basis of a unified sizing even if for Canada an oversizing of sizes lower than AWG 10 of 30% for conductors with temperature of 90°C and 10% for conductors of 105° is recommended.**

The adoption of AWG 14 is always recommended as minimum limit at the feed conductor section.

EXAMPLE

A feeder conductor supposedly protected by a **140U** circuit breaker that powers the following loads:

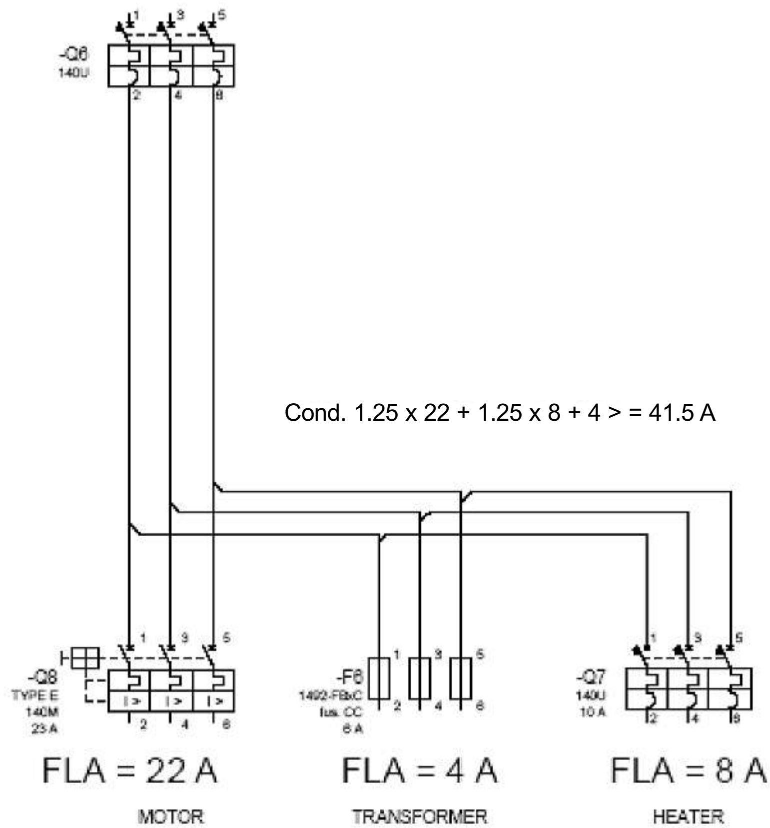
- motor with FLA of 20 A protected by **140M** type 23 A combination motor controller;
- control transformer with rated current of 4 A, protected by DC fuse of 6A in a **1492-FBxC** fuse holder;
- heater resistor with 8A rated current protected by a **140U** circuit breaker.

All the rated currents are called "FLA" for simplicity's sake.

On the basis of the previous equation we find that the capacity of the feeder conductor should not be lower than (1.25 x 22) A + (1.25 x 8) A + 4 A **= 41.5 A.**

From the table 28.1 of UL 508 A the AWG 6 section is obtained with a 55 A capacity.

The same calculation must be applied if the data is required for power conductors of the machine and relative connection power blocks.



4.3 Reduction of the sections down line from the feeder conductors

Once the *feeder conductor* has been cleared, it is also possible to define the branches with a smaller cross-section called like *"tap conductors"*.

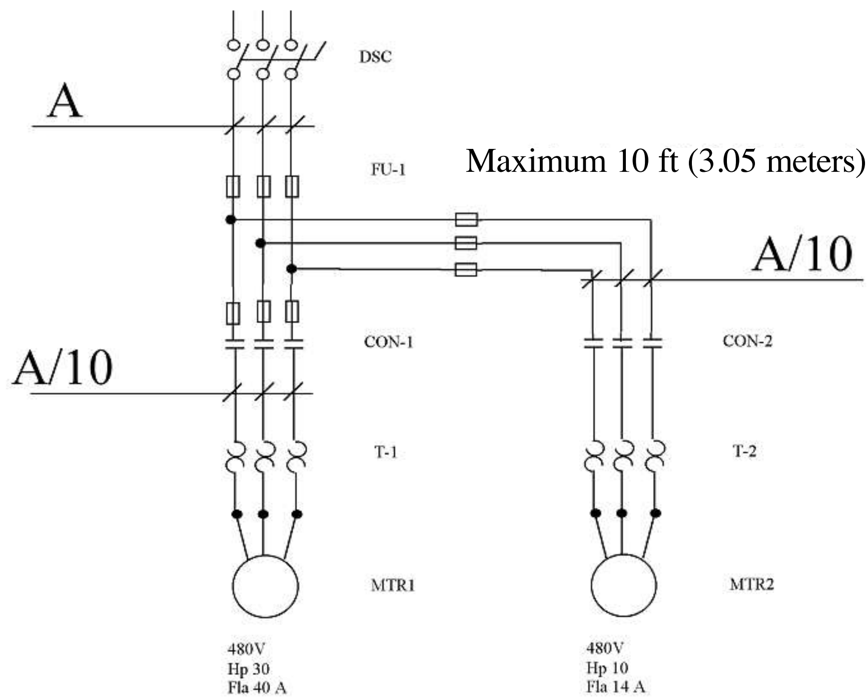
The rules regarding these conducts are only contained in the NEC and the CEC and are very similar.The tap conductors are divided on the basis of length:

a) taps (cables) less than 3 m (10 ft) long: all the conditions imposed should be respected: the capacity of the conductor should always be adjusted to the load powered (for example if the load is a motor, the derivation should have a capacity of at least 125% of its FLA).

- the tap should not extend further than the BCP of the powered loads
- to guarantee the mechanical protection, the derivation should always be enclosed in conduits or raceways (not walk over covers) the connection points obviously excluded. The CEC furthermore requires the conductors to be metallic.

Furthermore the NEC provides:

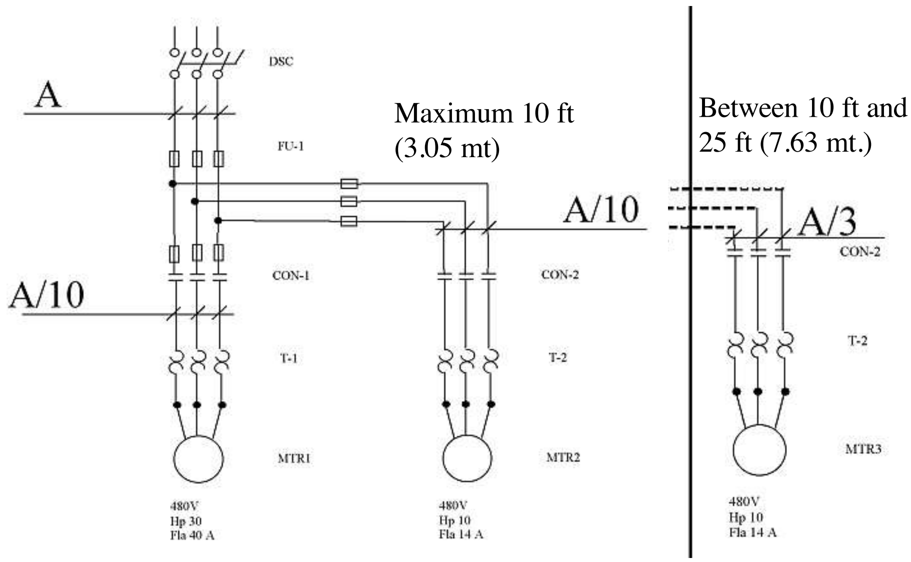
- if the tap leaves the panel it shall have a capacity of not less than 1/10 of the size of the feeder protection



b) <u>taps (cables) of a length no more than 7.5 m (25 ft.):</u> all the conditions set should be respected:

- the size of the conductor should always be adjusted to the powered load
- the capacity of the conductor should not be less than 1/3 the size of the feeder protection
- each tap should feed a single BCP (there is no limit to the number of loads downstream from the BCP provided the relative conductors are protected by the BCP on the basis of the rules already seen)
- mechanical protection should be guaranteed. The use of conduits or raceways (not walk over covers) is recommended.

Under no circumstances may a tap conductor be derived from another tap conductor. Derivations with reduced cross-sections can only be made directly from the feeder.



5. Sockets and plugs

In North America a receptacles is also permitted as a switching device provided that it follows these following requirements:

- The receptacle is single voltage
- The motor or load is not more than 2 Hp
- The sizing is less than 125% of the rated current of the motor or the load
- It is installed with a cable of no more than 6 m (20 ft) long
- The socket and plug conform in terms of the voltage and amperes with the Nema Types defined in the NEC.

6. Fuses

Fuses are considered by many to be the best protection against short circuits.

The spread of fuses has lead to the need to establish construction standards, something that NEMA (association of construction of electrical equipment) has seen to. At present 13 different types of power fuses are recognized (that are

suitable as *Branch Circuit Protection* and as general panel protection) and several other types of control fuses (adapted to the use of just control circuits: *Supplemental Fuses).*

Note that the NEMA standards are construction standards: the fuses are, in terms of sizes and dimensions, identical regardless of the manufacture (as it happens in Europe). Fuse holders are made especially for some types of fuses as indicated in the approval markings of the certifying NRTL laboratory.

North American fuses differ from the European types and cannot be interchanged. Furthermore they do not correspond with any EN harmonized standard rule.

A list of the main types of fuse identified by the Underwriters Laboratory is given:

In the USA the NFPA 79 standard for *Industrial Machinery* (and the relative UL508A section) recommends the use of CC, J, RK-1, RK - 5 fuses (already highlighted). **It is recommended that the design be unified through the adoption of these types in the electrical equipment.**

Furthermore UL508A prohibits the use of H, H (renewable), K, G and T fuses in the Industrial Machinery: it is an additional UL provision.

Fuse type	UL standard	Definition	Adjusted for power	Control circuits
C	248 – 2	Class C Fuses	x	x
CA, CB	248 – 3	Class CA and CB Fuses	x	x
CC	248 – 4	Class CC Fuses	x	x
G	248 – 5	Class G Fuses	x	x
H	248 – 6	Class H Fuses (Non Renewable)	x	x
H (Renewable)	248 – 7	Class H Fuses Renewable	x	x
J	248 – 8	Class J Fuses	x	x
K	248 – 9	Class K Fuses	x	x
L	248 – 10	Class L Fuses	x	x
Plug fuses	248 – 11	Plug Fuses	x	x
R (RK-1, RK-5)	248 – 12	Class R Fuses	x	x
Special Purpose	248 – 13	Special Purpose	x	x
Supplemental Fuses	248 – 14	Supplemental Fuses	x	x
T	248 – 15	Class T Fuses	x	x

[a] the semi-conductor type Special Purpose fuses can be used as protection in power circuits (BCP) only if explicitly required in the label or in the instructions of the component to be protected.

6.1 - Class CC fuses

These are the most common and used in the protection of transformers, loads and motors (they have both a “Fast” intervention curve and a “Time Delay” curve), they are ideal for Feeder and Branch circuits and are similar to European 10x38 fuses. Their limit is the size; ranging only from 0 to 30 A.

Attention: these fuses require their own dedicated fuse holder the 1492-FB for CC class fuses, as specified in the NEC.

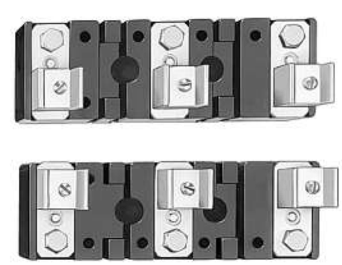
CC class fuse

Bull fuse holder 1492–FB and 140–F

6.2 Class J fuses

These are the most common fuses for the protection of electrical panels, in switches with fuses. Outstanding for the protection of equipment, motors, actuators etc.(they have both a “Fast” intervention curve and a “Time Delay” curve) they have different construction shapes as the size varies (range from 0 to 600 A). They need their own dedicated fuse holder.They are not interchangeable with fuses of other classes.

Class J fuse



Bull. 1491 fuse holder.

6.3 Class K and RK fuses

These are fuses that are suitable for the protection of electrical panels, in switches with fuses, motors actuators etc.(they have both a “Fast” intervention curve and a “Time Delay” curve) they have different construction shapes as the size varies (range from 0 to 600 A).They need their own dedicated fuse holder.They are not interchangeable with fuses of other classes.

1. Starting, load protection and motors (Branch Circuit)

1.1 The different types of branch circuit

The main types of power circuits can be distinguished inside the electrical equipment of a machine:

- *motor* motor start
- *lighting* lighting
- *heater* heater
- *appliance* general device
- *receptacle* (power) connector

The different types of *branch circuit* will be described in the following paragraphs.

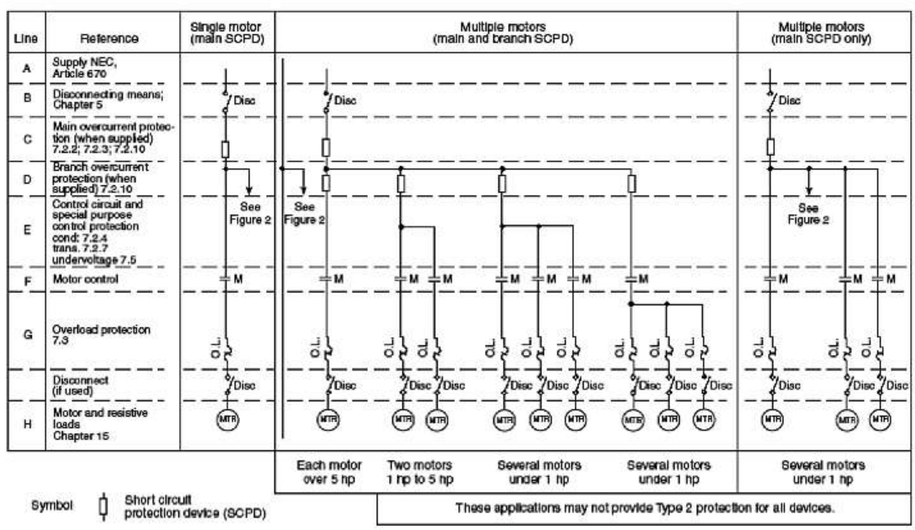


FIGURE A.7.2.1(a) One Line Representation of Electrical System Power Distribution.

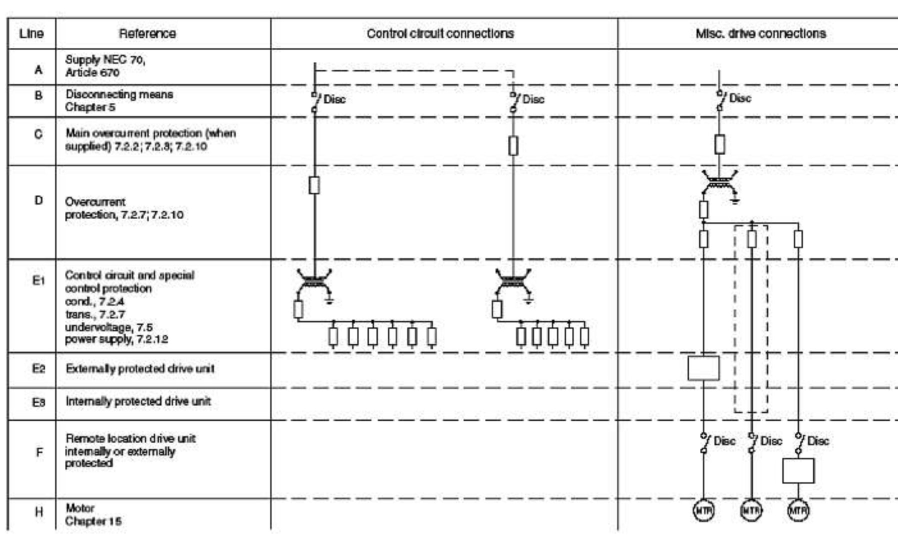


FIGURE A.7.2.1(b) One Line Representation of Electrical System Power Protection.

1.2 Motor branch circuit

The *motor branch circuit* is identified with what is generally called **motor starter.**

In fact there are various types of motor starters (called direct, star-delta, with inversion etc) and for each of them there are special regulations.

This document will initially refer to the simplest case of a direct start then it'll go onto considering other mostly common cases. North American and Canadian Standards are very similar and any differences will be clearly shown.

The motor start can be made with different methods that are called *"types"*. A summary table of the recognised types contained in the UL 508 *"Industrial Control Equipment" standard.*

Construction Type	Construction Requirements, Paragraphs	Component[a]	Component Standard	Component Function			
				Disconnect	Branch Circuit Protection	Motor Control	Motor Overload
A	76.4 – 76.8	Manual Disconnect	UL 98 or UL 1087	X			
		Fuse	UL 248 series		X		
		Magnetic or Solid State Motor Controller	UL 508			X	
		Overload Relay	UL 508				X
B	76.4 – 76.8	Manual Disconnect	UL 98 or UL 1087	X			
		Motor Short-Circuit Protector	UL 508		X		
		Magnetic or Solid State Motor Controller	UL 508			X	
		Overload Relay	UL 508				X
C	76.4 – 76.8	Inverse-Time Circuit Breaker	UL 489	X	X		
		Magnetic or Solid State Motor Controller	UL 508			X	
		Overload Relay	UL 508				X
D	76.4 – 76.9	Instant-aneous-Trip Circuit Breaker	UL 489	X	X		
		Magnetic or Solid State Motor Controller	UL 508			X	
		Overload Relay	UL 508				X
E[b]	76.3.1 – 76.6, 76.8 – 76.13	Self-Protected Control Device	UL 508	X	X	X	X
F	76.3.1 – 76.9	Manual Self-Protected Combination Controller	UL 508	X	X		X
		Magnetic or Solid State Motor Controller	UL 508			X	

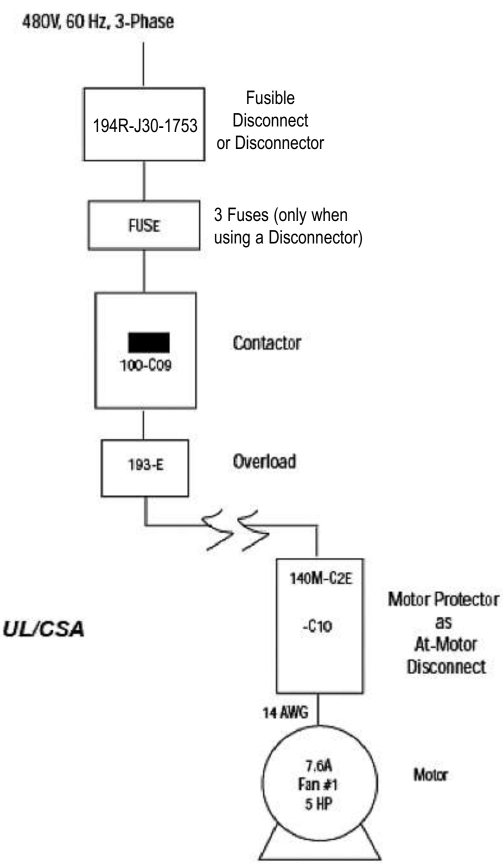
[a] Tests are conducted on the individual components per the applicable requirements from the UL Standards in the table.
[b] See 76.11.

It is particularly interesting the recent introduction of *"Type F"* that joins a *"Type E"* motor protector and a contactor in an approved assembly, with its own specific characteristics which are different from those of the individual components.

1.2.1 Motor Starter "Type A"

This is the classic North American motor starter that consists of:

- Sectioning device (UL 98)
- Fuses UL 248
- Contactor
- Overload relay



Motor Disconnecting – UL/CSA

1.2.2 Motor Starter "Type B, C and D"

Motor starter Type B is rarely used.

Motor starter Type C consists of:

- Automatic Circuit Brealer UL 489 – inverse time / thermal magnetic
- Contactor
- Overload Relay

Motor starter Type D consists of:

- Automatic Circuit Brealer UL 489 – instantaneous trip / magnetic only
- Contactor
- Overload Relay

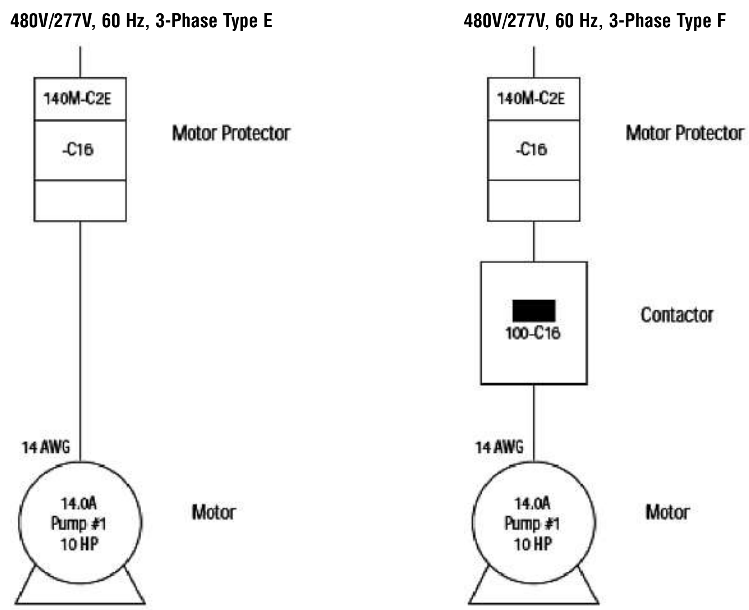
1.2.3 Motor Starter "Type E" and "Type F"

The motor starter Type "E" consists of:

- Self protected combination motor starter 140M with 140-M-CTE

The motor starter Type "F" consists of:

- Motor protector 140M with 140-M-CTE
- Contactor



In the IEC area the motor protectors are considered, for all practical purposes, as automatic switches which are able to protect against over-currents as well as against short-circuits.

On the contrary in North America there is a clear difference between "Circuit Breaker" UL 489 automatic switches and "Combination Motor Controller" UL508 motor protectors.

Within the standard UL 508 there are two different certification procedures of the motor protectors such as:

- *"manual motor controller":* It has the function to *"disconnect"* (load sectioning), *"motor control"* (load switching), *"motor overload"* (protection against over-loads) and it does not perform the magnetic protection.

- *"manual self-protected combination motor controller (Type E)":* It performs the same functions as the *manual motor controller* and it also guarantees *"branch circuit protection"* (protection against short-circuit).

1.2.3.1 Differences between a motor protector "Manual Motor Controller" and a "Manual self-protected combination motor controller Type "E" in the United States[1])

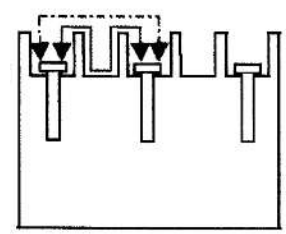
The size of the product, for instance, is one of the most important elements of differentiation between UL 489 and UL 508. Generally speaking, the devices according to UL 489 have a physical size definitely bigger than the components of the UL 508, in order to satisfy the isolation distance imposed by the norms and by the NEC regarding the feed circuits or feeder.
Therefore, if the motor protector is used in North America as a protection device "Type E", it means that it must have the same distances at the connection side to the line required according to UL 489, which have been changed and is included also in the UL 508 edition of July the 16th, 2001 for this kind of products:

- 1 inch (25,4 mm) for an aerial distance
- 2 inches (50,8 mm) for a above-ground distance;

Above-ground ←——→

aerial ←- - - - -→

	Before July the 16th, 2001	After
Aerial distance	3/8″	1″
Distance between two surfaces	1/2″	2″



In general, these distances are higher than those built in the components with an IEC standard. In fact, all the motor protectors which are manufactured according to the European standard, turned out to be too "small" (apart from some exceptions) to be compatible with the dimensions imposed by the UL 508 standards. Therefore, they lose their protection function against over-currents (short-circuit).

A motor starter manufactured in Europe using an IEC rated manual motor starter together with a contactor, in case of application in North America shall be integrated with fuses or UL 489 automatic circuit breaker in order to provide protection against short circuits.

1) For Canada and particularly for the CSA, the certification of motor protectors has not been updated on the restrictions included in the UL 508 (e.g. new aerial distances and between the surfaces).

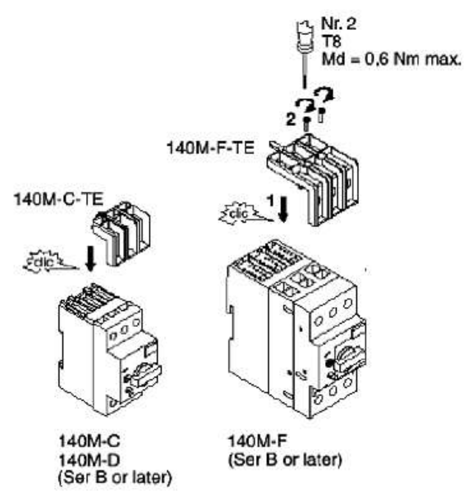
For instance the motor protectors of the 140 M series with one *"specific stretcher accessory" feeder adapter 140M-C-TE* to be installed on the connection side to the line, comply with the new distances included in the UL 508.

With this special accessory, the motor protector can be certified as a Manual self-protected combination motor controller Type "E". Therefore, it is a unique device which combines sectioning, protection against over-currents and thermal protection without the necessity of using fuses or other external devices.

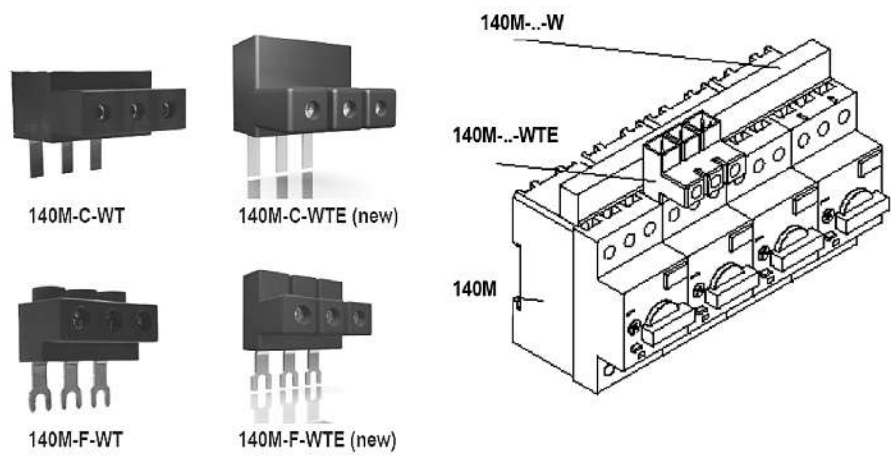
EXAMPLE

If we take the motor protectors of the 140 and 140M family:

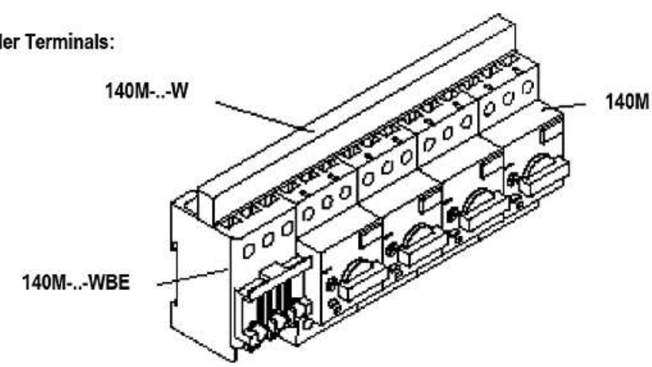
- **140M-C, -D** are *manual motor controllers,* but they can also be used as *type E* if the accessories **140M-C-TE** are being used for the single motor protector.
- **140M-F** are *manual motor controllers,* but they can also be used as *type E* if the accessories **140M-F-TE** are being used for the single motor protector.



The certification as TYPE "E" remains the same even if the distribution combs of the 140M- .. – W series are used only when combined with the new connection systems such as the 140M-C-WTE or the 140M-F-WTE.



New Busbar Feeder Terminals:



1.3 Sizing of the protections and of the branch circuit components.

1.3.1 Three-phase direct starter

The reference schematic is:

Branch Circuit Protection: the last protection against over currents and in particular, short circuits.

Controller: contactor

Overload protection: protection against overloads

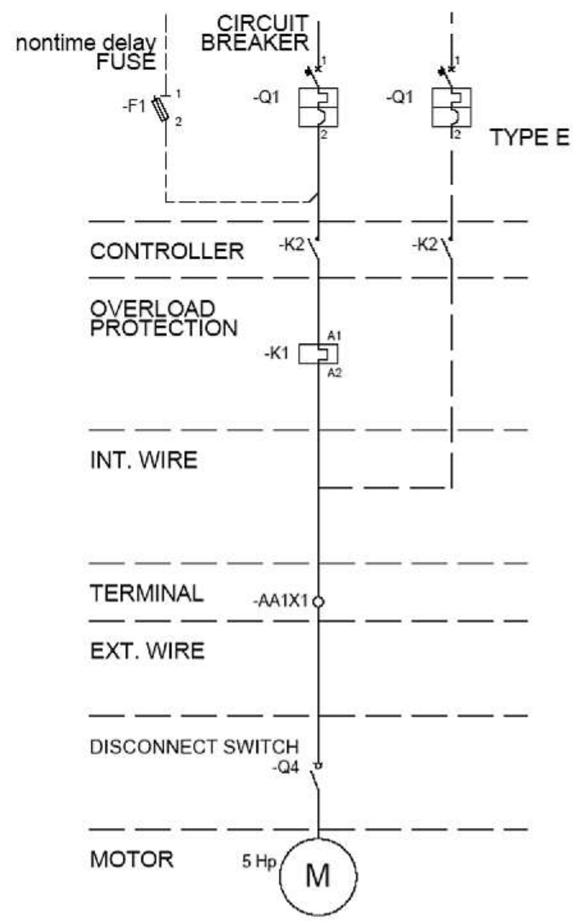
Internal conductors & wires inside the panel

Terminal: interface terminal between the panel and on the machine

External: conductors&wires outside the panel

Disconnect Switch: disconnect switch on the machine for maintenance of the motor

Motor: three/single phase electrical motor



<u>This means that all the components described must be approved by an NRTL for their intended function. Any exceptions shall be clearly indicated.</u>

Design example:
5hp three-phase motor (3,7 kW)
480V

Once the sizing has been completed, the components shall be chosen in the case where the motor start has to be affected following the construction criteria IEC and UL/CSA *"normal"* components with double approval

- NEMA special components for North America

For the drawing and the dimension of the motor start, we will proceed from the motor up to the branch protection by sizing the field insulator, the thermal protection, the meter for the protection against short-circuits (fuses, automatic switch or motor protector).

1.3.1.1 Motor

First of all it is necessary to clearly identify the rated current of the motor that must be used for the scaling. In North America two values must be distinguished:

a) *nameplate current:* the current rating plate

b) *Full Load Ampacity* ***(FLA):*** the full load current indicated in special tables

- <u>DC motor</u> (direct current): tab. 430.147 of the NEC (0.25<hp<200), tab. D2 of the CEC (0.25<hp<200), tab. 50.2 of the UL508A (0.1<hp<200);the UL508A table is the same as that of the NEC, while the CEC tables brings values that are generally inferior.
- <u>single-phase</u> (alternate current): tab. 430.148 of the NEC (0.167<hp<10), tab. 45 of the CEC (0.167<hp<10), tab. 50.1 of the UL508A (0.1<hp<50); the tables present the same values.
- <u>two-phase</u> (alternate current): tab. 430.149 of the NEC (0.167<hp<10), tab. 50.1 of UL508A (0.1<hp<200), no table in the CEC; the tables present the same values, but UL508A table is more complete.
- <u>three-phase</u> (alternate current): tab. 430.150 of the NEC (0.5<hp<500), tab. 44 of the CEC (0.5<hp<500), tab. 50.1 of the UL508A (0.1<hp<500); above 3 hp all the tables have the same values, under 3 hp the CEC table has slightly higher values.

The FLA value in the table is obtained from tests done on reference motors (in accordance with the NEMA standard) under normal conditions of use: it is known that the reference motors have low level electrical characteristics so the <u>FLA is always higher than the current on the rating plate</u> of a normal motor of open power.

The *current nameplate* must **always** be used for the sizing of the overload protection.

For all the other NEC and UL dimensions the use of the highest value between the FLA table and the current on the rating plate (generally the FLA) is required; the CEC always recommends the use of the rating plate value, while admitting the FLA if it is unknown.

EXAMPLE

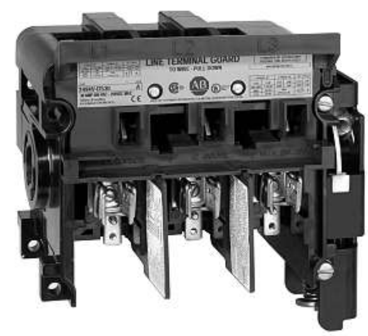
In the example being examined it is supposed that the rating value is unknown: in this case reference is made to the FLA table. With reference to UL508A, table 50.1 shows

Horse-power	110 – 120 V			220 – 240 V[a]			380 – 415 V		440 – 480 V			550 – 600 V		
	Single Phase	Two Phase	Three Phase	Single Phase	Two Phase	Three Phase	Single Phase	Three Phase	Single Phase	Two Phase	Three Phase	Single Phase	Two Phase	Three Phase
3	34	16.6	19.2	17	8.3	9.6	10.9	6.1	8.5	4.2	4.8	6.8	3.3	3.9
5	56	26.4	30.4	28	13.2	15.2	17.9	9.7	14	6.6	7.6	11.2	5.3	6.1
7-1/2	80	38	44	40	19	22	27	14	21	9	11	16	8	9
10	100	48	56	50	24	28	33	18	26	12	14	20	10	11

The same value is also reported on the same NEC and CEC tables.

1.3.1.2 Disconnecting Means

194-E UL



1494 NEMA

The term *"disconnecting means"* indicates a selector switch for the break off of one or more motor starters for the purpose of carrying out safe servicing.

In NEC and CEC it is specified that a sectioning is necessary:

- for each motor starter;
- for each motor.

Is it enough to have a single device in order to perform all these functions, (e.g. a main disconnecting switch)?

<u>*No, this device must only be devoted to the motor start only (in addition to the main disconnect switch).*</u>

As a general rule, this function is performed by the motor protector or by the *"suitable as motor disconnect"*.

A particular case which one cannot ignore is when there is no visibility between the motor and the panel feeding it. The safety regulations for the installation of a disconnecting means in sight of the motor don't permit unauthorised closures during maintenance.

The local disconnection can be avoided where it is not practical or where there are maintenance and surveillance procedures that prevent the access by non-specialist personnel, providing that the disconnecting device on the panel (for example the motor protector) is fitted with means for locking in open position (a padlock or the like).

The sizing of the disconnecting means for a motor starter depends on how many motors are sectioned and the type of sectioning used:

a) single motor, disconnecting device defined in current: the rated current of the disconnecting means must not be less than 115% the current of the motor;

b) single motor, disconnecting device defined in hp (power): for NEC and CEC it is enough that the size of the disconnecting means in hp is greater than the power of the motor, while UL508A requires to establish the current on the basis of tables 50.1 and 50.2 and then apply the 115% rule described in the previous point;
It is recommended that you follow this criterion for simplicity' sake.

c) more than one motor: refer to the case of a single motor with current equal to the sum of all the motor currents (as usual the FLA for the USA and value of the motor plate for Canada).The sizing is done in current by applying the lower limit of 115%: in the case of the disconnecting means defined in hp (power) the value obtained from tables 50.1 and 50.2 must be taken as rated current.

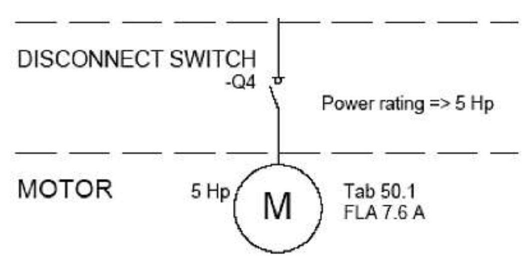
Note that a self protected combination motor starter type E cannot section multiple motors.

EXAMPLE

The disconnecting means chosen must have power sizes not lower than 5 hp.

The suitable IEC/UL/CSA component is a **194E-25** disconnect switch with a *rating* of 5 hp.

In a NEMA starter a **1494F-N30** able to section 7.5 hp will be used: if the installation is directly on the machine a **1494F-NP30** *"enclosed" disconnect can be used.*



1.3.1.3 Overload protection

193-E UL

592 NEMA

The thermal protection is required for all the motors regardless of the size, unless the motor is marked and authorised as self protected (impedance of the windings is sufficient to prevent overloads).

Thermal relays, fuses, all the overload relays are admitted as protection from the overload.

The power converters e.g. the reverse devices can perform this function only if explicitly indicated in the instructions and only if the related instructions comply with to the letter: some converters check the overload internally make checking the through energy (I^2t), other converters require the use of thermostats or thermocouples. Failure to comply with the instructions will mean the protection function is nullified.

The motors can have integrated protection providing that the assembly is certified in all its parts: the use of self-protected must be shown in the schematics.

The maximum protection calibration must not exceed 115% of the rated current on the plate. In the case of slow intervention, on start up or during normal functioning, the protection can be increased up to 130%: in the case of components that can be regulated the correct calibration must be indicated on the schematics.

In the case of thermal relays with resistors that can be replaced (NEMA construction relays) the proper calibration must be shown on the schematics and the catalogue code of the element be replaced must be attached.

EXAMPLE

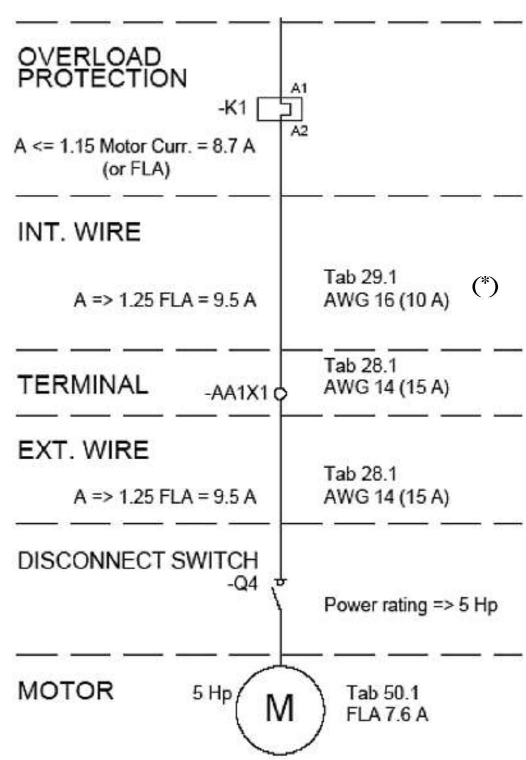
In the example the plate current is suggested and if it is unknown FLA figures are used.

The calibration must not be greater than 7.6 A x 1.15 = 8.7 A

If an overload relays with an adjustable threshold is used the device **140M-C2E-C10** with adjustability range between 6.3 A and 10 A will be selected.

If a IEC/UL/CSA thermal relays is used the choice will fall on the **193-ED1DB** (electronic) with regulation range between 3.2 and 16 A.

At the moment of installation the overload relays and electronic O/L relays must be adjusted at 100% of motor FLA.



(*) Effective March 1, 2007 internal wiring < 14 AWG is only permitted in industrial machinery panels, and must be protected by a device marked suitable for connection and protection of that gauge of wire.

1.3.1.4 Controller

100-C UL

500 NEMA

The definition of *controller* is somewhat generic because this term refers to any components that enable a load to be commanded: for example even a motor protector when manually operated is considered to be a controller.

In this analysis the *magnetic controllers,* or contactors are taken as a reference.

In the case of a direct start the contactor is easily chosen in the catalogue while respecting a small number of obviously rules:

- having a rated voltage that is not smaller than the one of the circuit;
- that the size (in amperes) is not smaller than the sum of the scaling of the controlled loads, in the simplest case of direct starting of a single motor it can be scaled on the power of the motor, in hp;
- be approved for the type of load controlled.

<u>Every motor must be controlled by a dedicated contactor.</u> An exception is admitted in the USA for *Industrial Machinery* in the case of a single contactor that has to co-ordinate the functioning of more than one load (mixed, not necessarily motors): the current is scaled and calculated as the sum of the rated currents of all the loads.

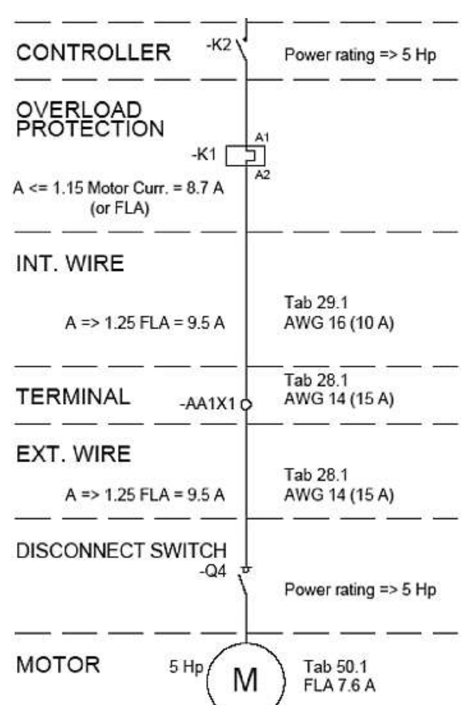
EXAMPLE

The contactor must be adapted for a voltage of 480V and must be suitably scaled to the motor.

In the case of direct starts the contactor can be scaled on the basis of the power: the contactor must therefore have a size of at least 5 hp.

The suitable IEC/UL/CSA component is a **100-C16x10** contactor with rating equal to 5 hp and a auxiliary NO contact.

In a NEMA starter a 5 hp **500-BOx930** and with a NO auxiliary contact is used.



1.3.1.5 Branch Circuit Protection (BCPD)

140-U

140F fuse holder

140M

The protection of the motor starter from the short circuit can be done in different ways

The most used components are: fuses, manual self-protected motor controller *"type E"*, automatic circuit breakers.

THE FOLLOWING ARE NOT ALLOWED: modular miniature circuit breakers (with the exception of those with UL 489 approval), motor controllers that are NOT "type E", fuses approved for control circuits.

<u>The size/calibration of the protection must not be more than the lowest value between the two following values:</u>

1) the product of the motor's full load current by a tabled coefficient; or
2) the required current from the restrictions shown on the approval "marking" of power components down line from the protection in question: in particular of contactors and overload protections.
   Two fundamental data are required by the NRTL at the time of the certification: the type of short-circuit protection to be used and its maximum current size.

If the size/calibration of BCPD is not above 115% of motor nameplate FLA, then it can also serve as overload protection.

The coefficients indicated in point 1) of the preceding list have been tabulated for every type of protection and motor. The table is identical in any standards.
An extract from NEC follows :

	Percentage of Full-Load Current			
Type of Motor	Nontime Delay Fuse[1]	Dual Element (Time-Delay) Fuse[1]	Instantaneous Trip Breaker	Inverse Time Breaker[2]
Single-phase motors	300	175	800	250
AC polyphase motors other than wound-rotor				
Squirrel cage — other than Design E or Design B energy efficient	300	175	800	250
Design E or Design B energy efficient	300	175	1100	250
Synchronous[3]	300	175	800	250
Wound rotor	150	150	800	150
Direct current (constant voltage)	150	150	250	150

Note: For certain exceptions to the values specified, see 430.54.
[1]The values in the Nontime Delay Fuse column apply to Time-Delay Class CC fuses.

It is known that the value calculated in the "current x coefficient" is the maximum ***magnetic*** *protection calibration value.*

For example, an *"inverse time"* automatic circuit breaker installed upline from a motor with a current equal to 10 A, should have a magnetic threshold of 10 A x 250% = 25 A. Automatic circuit breakers according to European standards normally have a magnetic threshold ten times that of the thermal threshold: thus a breaker calibrated magnetically at 25 A is able to bring to 2.5 A capacity before the thermal protection trips in and this is not suitable for the motor under consideration. The nub of the problem is the fact that for the NEC and the CEC the circuit breakers must have a fixed thermal and magnetic adjustable in a wide range; the construction criterion is therefore opposite that of the European.

Nevertheless NEC/CEC never make precise reference to the magnetic threshold, but only to a general calibration: this leaves the margin on the use of automatic circuit breakers approved as BCP but of a European type in which the calibration defined on the basis of the product "current x coefficient", is applied to the adjustable thermal threshold.

On the contrary, the *"type E"* motor starters also called *"self-protected combination motor controller",* are not taken into consideration because the magnetic tripping value is fixed constructively at 1200 to 1300% of the current of the motor and this value is implicitly accepted in which their use is permitted. In the *"type E"* motor starter, only the thermal protection is calibrated.

The NEC and the CEC provide for the following standard sizes/regulations for fuses and circuit breakers: 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000 and 6000. Additional sizes for fuses are 1, 3, 6 and 10.

The protection device must have size/regulation that does not exceed the product "current x coefficient", but if the value calculated does not coincide with a standard size/regulation, the use of the one immediately above is acceptable.

Take for example a 10 A motor: using rapid fuses *(nontime-delay)* the coefficient is 300% and the product is equal to 10 A x 300% = 30 A, standard size. On the contrary when *(time-delay o dual element)* delayed fuses are used, the coefficient is 175% and the product equals 17.5 A that is not the standard size: in this case fuses up to 20 A can be used.

If the values indicated in the table are not sufficient to guarantee the start up of the motor without the slow intervention of the protection, the tabulated values can be used up to:

• fuses without delay or CC class up to 600 A:	400%
• fuses without delay over 601 A:	300%
• (dual element delayed fuse:	225%
• automatic thermomagnetic cutout not above 100 A:	400%
• automatic thermomagnetic cutout not above 100 A:	300%
• magnetic cutout for Design B, C or D motors:	1300%
• magnetic cutout for Design E motors:	1700%

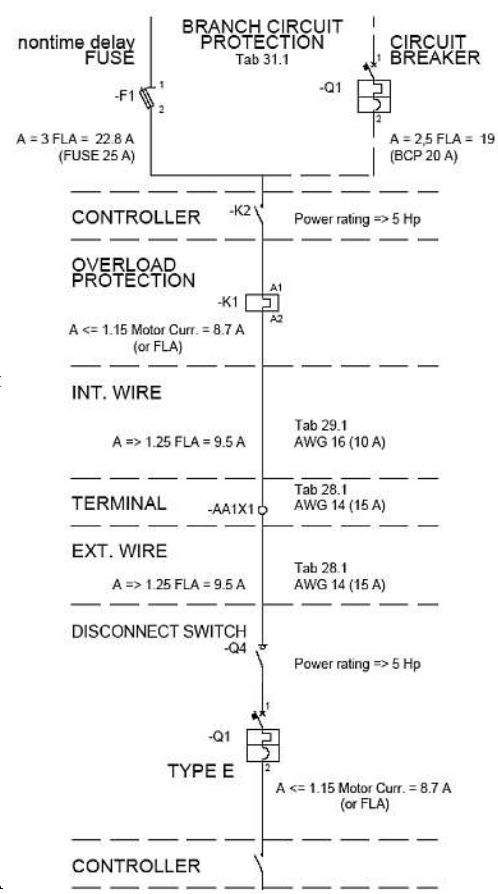
Use of instantaneous trip (magnetic only) breakers must be part of a listed combination of MCP + Contactor + O/L Relay. Alternatively, UL panel shops can have combinations procedure described.

EXAMPLE

Furthermore it is assumed that the restrictions of the contactor and the thermal relay are negligible for the purposes of choice and scaling of the BCP.

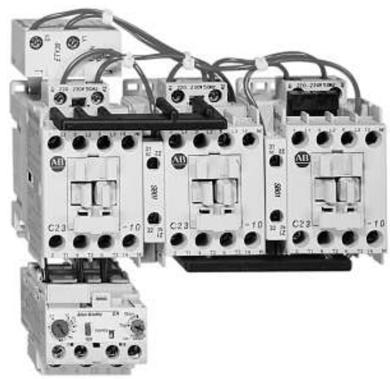
a) Not-delayed fuses: the maximum size is 7.6 A x 300% = 22,8 A that is not the maximum standard for which the use of fuses up to 25 A is legitimate. CC fuses (dim. 10x38) are chosen. The suitable fuse holder is the **1492-FB3C30 or 140F-03C-C30.**

b) automatic circuit breaker: the maximum size is 7.6 A x 250% = 19 A that is not the standard size so the use of a 20A circuit breaker is legitimate.
The thermo magnetic for this use is the **140U-H2C3-C20**, with an interrupting capacity of 35 kA at 240 V.



c) Motor protector type E: the **140M-C2E-C10** previously chosen on the basis of the thermal protection is kept. The additional use of fuses or magnetic only circuit breakers is not required, provided the spacing adapter **140M-C-TE** is used (as is clearly indicated on the label).

1.4 Wye-delta starting



170

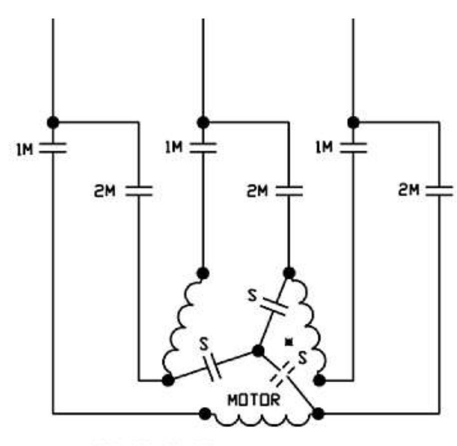
540

The wye-delta starters are dealt with special rules and tables and the UL508A in particular dedicates an entire paragraph to it.

The reference schematic is:

CONTACTOR SEQUENCE				
CON-TACTOR	START		TRAN-SITION	RUN
1M		X	X	X
2M				X
S	X			

1M line contactor
2M delta
S wye



On the basis of the functioning sequence the functioning conditions of the individual contactors are specified:

- **1M** "closed" when the motor is wye closed, "open" when the motor is running to full capacity;
- **2M** "closed" when the motor is being started, "open" when the motor is running to full capacity;
- **S** "closed" when the motor is closed, "open" when the motor is being started.

For each contactor it is possible to define a current value to be opened, called *"break current"*, and a current value to be closed, called *"make current"*.

The following terms can be used as an analogy with the motors:

- *"Locked Rotor Ampacity"* **(LRA)** is the current established at the moment the contactors close, i.e. the *make current;*
- *"Full Load Ampacity"* **(FLA)** is the current that the contactor must open to interrupt operation, i.e. the *break current.*

This is the value normally indicated in the catalogues

For the motors it is specified that LRA = 6 x FLA unless they are specifically marked with a different ratio.

For contactors this is a dummy ratio and by definition LRA = 6 x FLA is imposed.

Contactor functioning currents

The delay set through the special timer for the passage from the wye to the delta must be sufficient to start up the motor: in this case the contactors switch a current with a similar to that of full capacity (the FLA of the tables). If instead the delay set is too short, the contactors switch, with the motor almost at standstill, a current with a value equal to that with the rotor blocked.

EXAMPLE 1

The extreme case of a start where the switching from wye to delta occurs with a stopped motor is hypothesised:

Contactor code	LRA	FLA
1M	0.33 x LRA motor	0.577 x LRA motor
2M	0.577 x LRA motor	0.577 x LRA motor
S	0	0.33 x LRA motor

A **20 hp** (15 kW) three-phase motor is assumed at **480 V** of which the rated plate current is unknown and the value of the current with the rotor blocked is unknown

From the table it is read that the FLA of the motor is 27 A and that LRA is 162 A (that is 6 x 27 A). In this case the operating currents of the contactors are:

Contactor code	LRA	FLA
1M	0,33 x 162 A z 53 A	0.577 x 27 A z 16 A
2M	0.577 x 162 A z 93 A	0.577 x 27 A z 16 A
S	0	0.33 x 162 A z 53 A

The choice of the contactors occurs as in a normal direct starting supposing that each of them commands a dummy motor with current, at fully capacity and with blocked rotor, equal to those calculated.

In the catalogue, the contactors are specified by power so it is necessary to convert the calculated current values into power output (hp). The procedure is opposed to that for obtaining the FLA: starting from the calculated current the three-phase motor is sought that, at 480 V, has an FLA that is not lower. The following is obtained

Contactor code	FLA calculated [A]	Motor power FLA print out	Contactor Power
1M	16	15 hp 21 A	100-C23 15 hp
2M	16	15 hp 21 A	100-C23 15 hp
S	53	50 hp 65 A	100-C72 50 hp

The fault for which the "wye" is larger than the line contactors and delta is immediately clear: this is a direct consequence of the case for which the switching occurs when the rotor is blocked.

EXAMPLE 2

The normal case is assumed with a start where the switching from wye to delta occurs when <u>the motor has already started at sufficient speed:</u>

Contactor code	LRA	FLA
1M	0.33 x LRA motor	0.577 x LRA motor
2M	0.577 x LRA motor	0.577 x LRA motor
S	0	0.33 x FLA motor

The same motor as in the previous example is assumed: **20 hp** (15 kW) a **480 V** of which the rated current and the value of the current when the rotor is blocked are unknown

From the table it is read that the FLA of the motor is 27 A and that LRA is 162 A (that is 6 x 14 A). In this case the operating currents of the contactors are:

Contactor code	LRA	FLA
1M	0.33 x 162 A z 53 A	0.577 x 27 A z 16 A
2M	0.577 x 162 A z 93 A	0.577 x 27 A z 16 A
S	0	0.33 x 27 A z 9 A

The choice of the contactors occurs as in a normal direct starting supposing that each of them commands a dummy motor with current, at full capacity and with blocked rotor, equal to those calculated.

In the catalogue, the contactors are specified by power so it is necessary to convert the calculated current values into power values (hp). The procedure is opposed to that for obtaining the FLA: starting from the calculated current the three-phase motor is sought that, at 480 V, has an FLA that is not lower. The following is obtained

Contactor code	FLA calculated [A]	Motor power FLA print out	Contactor Power
1M	16	15 hp 21 A	100-C23 15 hp
2M	16	15 hp 21 A	100-C23 15 hp
S	9	7.5 hp 11 A	100-C12 7.5 hp

Of course the wye and delta contactors remain the same while the wye is now of a smaller size.

Scaling in accordance to North American criteria as just shown, while following precise tables defined in UL508A, brings us to make product choices identical to the ones of the drawings done in accordance with European criteria.

EXAMPLE 3

The normal case is assumed with a start where the switching from wye to delta occurs when the motor has already started at sufficient speed: <u>It is furthermore supposed that the motor is standard: LRA (blocked rotor current\) = 6 x FLA (full load current).</u>

On the basis of the hypothesis made it is not necessary to size the contactors on the basis of the currents but reference may be made to table 33.3 of UL508A. This table on the basis of the power and voltage of the motor defines the NEMA size of the contactors to use: the NEMA size is a construction size that is shown in the catalogue or on the component.

The same motor as in the previous example is assumed: 20 hp (15 kW) a 480 V.

Size of controller	Size of contactor[a]		3-phase horsepower			
	M1 and M2	S	60 Hz	60 Hz	50 Hz	60 Hz
			200 volts	230 volts	380 volts	460 or 575 volts
1YD	1	1	10	10	15	15
2YD	2	2	20	25	40	40
3YD	3	3	40	50	75	75
4YD	4	4	60	75	150	150
5YD	5	5	150	150	250	300
6YD	6	6	300	350	500	700
7YD	7	6	500	500	800	1000
8YD	8	7	750	800	1000	1500
9YD	9	8	1500	1500	2000	3000

The line to be used is the second, already highlighted, for the motor values between 15 hp and 40 hp: il *"NEMA size"* required is 2 for all three contactors.

To make the example clearer the contactors manufactured according to NEMA standards, the 500 series is looked for in the catalogue.

It is immediately noted that the choice of the components is made on the basis of criteria that differs from the European criteria: there are not categories of use; the contactors are divided first of all on the basis of the use provided for and then on the basis of the NEMA size.

From the catalogue, we find that the contactors for motors, size 2, suitable for the start in the example is the 500-COx930. No other type of sizing is required.

EXAMPLE 4

The case is assumed of a start where the switching from wye to delta happens when the motor has already started at sufficient speed, but the motor is marked with a different ration between the locked rotor current and the full load current.

The following is assumed: LRA = **9** x FLA.

The ration different from 6, between LRA and FLA obliges us to calculate the sizes of the contactors because table 33.3, cited in example 3, is no longer applicable.

Contactor code	LRA	FLA
1M	0.33 x LRA motor	0.577 x LRA motor
2M	0.577 x LRA motor	0.577 x LRA motor
S	0	0.33 x LRA motor

A three-phase **20 hp** (15 kW) at **480 V motor is assumed.** From the table it can be seen that the motor's FLA is 27 A: it follows that the LRA is 243 A (i.e. 9 x 27 A). The functioning currents of the contactors are:

Contactor code	LRA	FLA
1M	0.33 x 243 A z 80 A	0.577 x 27 A z 16 A
2M	0.577 x 243 A z 140 A	0.577 x 27 A z 16 A
S	0	0.33 x 27 A z 9 A

The choice of the contactors occurs as in a normal direct starting supposing that each of them commands a dummy motor with current, at fully capacity and with locked rotor, equal to those calculated.

In the catalogue, the catalog numbers are specified by power so it is necessary to switch the calculated current values into power output values (hp).

As far as the FLA is concerned these are identical to what is obtained in example 2, but in this case the line and delta contactors must be sized also on the basis of the LRA of the dummy motor. It should be kept in mind that the contactors still equal LRA = 6 x FLA. It's obtained

Contactor code	Dummy motor	Contactor ex. 2	
	FLA [A] LRA [A]	Code Power [hp]	FLA [A] LRA [A]
1M	16 80	100-C23 15 hp	21 126
2M	16 140	100-C23 15 hp	21 126

The line contactor satisfies the sizing conditions also in this case but the delta contactor is smaller than the LRA.

A correct choice requires a contactor with

LRA contactor >= LRA motor = 140 A

Therefore

6 x FLA contactor >= 140 A

x FLA contactor >= 140/6 23.3 A

From the FLA table it can be deduced that the contactor that fully meets this condition must have a power of 20 hp at 480 V (FLA equal to 27 A): from the catalogue the 100-C30 is chosen.

Contactor code	Dummy motor	Contactor ex. 2	
	FLA [A] LRA [A]	Code Power [hp]	FLA [A] LRA [A]
2M	16 140	100-C30 20 hp	27 162

Sizing of protections

Protection from the short circuit (BCPD) remains the same and is calculated over the entire FLA of the motor.

The thermal protection must be installed downline from the line contactor(M1) and with calibration of no more than 1.15 times the 57.7% of the motor's FLA. Attention must be paid to this requirement because very often a single overload relay is used as protection both thermally and magnetic but it is not accepted in this circuit schematic since it does not guarantee protection while the motor is starting up.

Sizing of conductors

The conductors, internal and external that bring the current to a wye-delta starting must be scaled on the basis of a factor of 1.25 (as already described); the reference current however changes, it is reduced to 57,7% of the motor current.

1.5 Group Installation

One of the main characteristics of the North American standard is the fact that they provide for *"group installation",* i.e. group installations that are regulated by specific instructions.

In general, these are installations in groups when there is a circuit where a single protection against short circuits (BCP) protects all the loads at once: the *motor group installation* (several motors down line from the same BCP) will be analysed later on. Note that each motor must have its own protection from overloads.

1.5.1 Dimensioning of branch circuit protections

The UL508A standard and the NEC provide for two or more motors (but also one or more motors and other loads) being able to be protected by a single *branch circuit* protection if they respect at least one of the listed cases:

1) When the BCP does not exceed 20 A at 125 V or 15 A at 600 V or less and
   - the full load current of each motor, FLA, does not exceed 6 A; and
   - the calibration and the type of protection of the *branch circuit* are co-ordinated with the restrictions of the components down line (i.e. indicated on the *marking* of the component);
2) When the calibration is the BCP type they respect the scaling parameters (previously defined) for each motor in the assembly.The start up of the largest motor must not cause untimely cut ins i;
3) When all the power components down line from the BCP protection are approved for the *group installation,* as indicated by the *marking* (of the NRTL certifier) on the component or on the instructions supplied with the components.

The size/calibration of the protection of the branch circuit must not be more than the lowest value between the two following:

- the size of the BCP is established by calculating the size required for the largest motor in the assembly (by doing this the product of the sizing current of the largest motor by a coefficient in the table, has already been seen for the individual motor start) plus the sum of the full load currents of the remaining motors and the nominal currents of all the other loads in the group; or
- the size of the BCP is chosen in such a way that all the power components do not exceed the value of the current specified in the *marking* as regards the *group installation* and the type of protection is the type specified in the same *marking* (for this purposes, the term *fuse* refers to a *branch circuit* protection connected with fuses and the term *circuit breaker* refers o an automatic cutout at reverse type).

Finally it should be noted that the *group installation* can only be carried out with automatic fuses and circuit breakers of the *"inverse time"* type: the overload relay of Type E cannot be used as BCP for a group installation.

EXAMPLE

A calculation is required of the size/calibration of a branch circuit protection for the following *motor group installation:* a **10 hp** (7.5 kW) motor and two **5 hp** (3.5 kW) **480 V** motors. The rating plate current is unknown

The FLA tables are: 14 A for the large motor, 7.6 for the other motors.

The *branch circuit* protection consists of a delayed fuse: its coefficient for the calculation of the BCP is 175%.

The protection size must be lower than:

14 x 1.75 A	value calculated as for individual motor start
7.6 A	FLA
7.6 A	FLA

for a total of 29.7 A. The size of the fuse immediately below is 25 A.

In the previous calculation the restrictions imposed by the downstream components have been ignored because generally larger sizes/calibrations are acceptable.

If, on the other hand, the maximum protection allowed delayed fuses of 20 A, this value would prevail over that calculated (25 A) and the fuses would have to be of sizes no greater than the 20 A allowed.

The CEC allows a *group installation* in accordance with points a) and b), while it limits the application of point c) to just machine tools and for wood working. The CSA does not lay down specific restrictions for the *group installation* so the BCP size limit is always obtained through calculation (the largest motor plus the other loads); maximum values are imposed for the size of the branch circuit *branch* circuit protection: 200 A up to 250 V, 100 A from 251 V up to 750 V.

The NFPA 79 standard for *Industrial Machinery* (and the relative UL508A section) allows a *group installation* in accordance with points a) and b), but point c) changes in the definition of the lowest value for the choice of the BCP: the one linked to the *markings* remains the same while the other is no longer obtained by a calculation but by a table (tab. 66.2 of UL508A) that binds the size of the BCP to the conductor with the smallest cross section downstream of the protection itself.

1.5.2 Sizing of conductors to the single motor.

In the case of *group installation* the circuit generally consists of conductors (called *branch circuits)* leaving the BCP protection to arrive at a distribution system (e.g. taps) from which the switching conductors powering the motors leave again, normally with a lower cross-section.

The conductors of each tap that power a single motor do not need to have an individual *branch circuit* protection from the short circuit provide the following conditions are respected.

1) no conductor to the motor must have a lower capacity than the *feeder* conductors capacity; **or**

2) no conductor to the motor must have a capacity lower than one third of that of the i *branch circuit* conductors (with a minimum value not less than the usual 125% of the motor current);the overload protection conductors must be the same as or shorter than 7.62 m and protected manually.

3) the conductors that go from the *branch circuit* protection to a *"manual motor controller,"* also approved as *"Suitable for Tap Conductor Protection in Group Installations",* can have a capacity of **no less** than 1/10 of the BCP calibration (rule included in the NEC until 2002) and in the new NEC ed. 2005 can have a capacity **not lower** than the size – calibration of the BCP (fuse or motor protector).

4) The conductors from the controller to the motor must have a capacity of no less than the usual 125% of the motor current.

   The conductors from the BCP to the controller must be adequately protected mechanically, segregated and they must be in lengths of not more than 3 m, <u>or</u> they must have a capacity of not less than that of the "branch circuit" conductors.

140M

A particular case of *group installation* is represented by the *"common bus"* in direct current: these systems consist of power rectifier that powers a short circuit that in its turn powers one or more inverters (and relative motors downline).

The UL508A standard gives specific instructions for these components:

- all the components in the system must be approved
- it is sufficient for there to be a single branch circuit protector up line from the rectifier the size/calibration of which must be no larger than the smallest value of the following two:
  a) the size required for the larger of the motors in the group plus the sum of the full load currents of the remaining motors (in the same way as required in point c) for the group installation); **or**
  b) the maximum size allowed by the rectifier, in the instructions or in the markings.

1.6 Three-phase, two-speed or Dahlander motor

The motors with multiple winding and those with Dahlander starting have multiple power supply terminal strips, each characterised by its own current characteristics. Every power entrance must be protected as if it were a single motor on the basis of the rules defined above.

The only exception allowed is the use of a single protection from the BCP short-circuit that however must be scaled in such a way as to meet the regulations for all the windings connected downline.

1.7 Reversal of direction

The reversal of direction requires an interlock between the two contactors that command the direction of turning.

The interlock can be mechanical or electrical, but there is an exception in the case of *Industrial Machinery:* in the USA the NFPA 79 standard (and UL508A in the relative section) require the use of both types of interlock.

1.8 – VFD Inverter and Softstarter

Inverter and softstarter demand that the branch circuit protection, against short-circuits, is made according to the indications of the instruction manual (as established in the UL 508A § 31.3.2).

> 31.3.2 The branch circuit protection for a single-motor circuit provided with a variable-speed drive shall be of the type and size specified by the manufacturer's instructions provided with the drive. When the instructions do not specify the type and size, a branch-circuit fuse or inverse-time circuit breaker shall be used and shall be sized based upon the input current rating of the drive multiplied by the percentage from Table 31.1.

Without this datum, it is allowed to size the protection as if it were a motor by multiplying the feed current of the drive, indicated in the manual, by the coefficient indicated in the relevant tables.

Table 1.C Minimum Recommended Branch Circuit Protective Devices

Voltage Rating	Drive Rating *kW (HP)*	Fuse Rating(1) *Amps*	140M Motor Protectors(2) *Catalog No.*	Recommended MCS Contactors *Catalog No.*
120V AC – 1-Phase	0.4 (0.5)	15	140M-C2E-C16	100-C12
	0.75 (1.0)	35	140M-D8E-C20	100-C23
	1.1 (1.5)	40	140M-F8E-C32	100-C37
240V AC – 1-Phase	0.4 (0.5)	10	140M-C2E-B63	100-C09
	0.75 (1.0)	20	140M-C2E-C16	100-C12
	1.5 (2.0)	30	140M-D8E-C20	100-C23
	2.2 (3.0)	40	140M-F8E-C32	100-C37
240V AC – 3-Phase	0.4 (0.5)	6	140M-C2E-B40	100-C07
	0.75 (1.0)	10	140M-C2E-C10	100-C09
	1.5 (2.0)	15	140M-C2E-C16	100-C12
	2.2 (3.0)	25	140M-C2E-C16	100-C23
	3.7 (5.0)	35	140M-F8E-C25	100-C23
	5.5 (7.5)	40	140M-F8E-C32	100-C37
	7.5 (10.0)	60	140M-G8E-C45	100-C60
480V AC – 3-Phase	0.4 (0.5)	3	140M-C2E-B25	100-C07
	0.75 (1.0)	6	140M-C2E-B40	100-C07
	1.5 (2.0)	10	140M-C2E-B63	100-C09
	2.2 (3.0)	15	140M-C2E-C10	100-C09
	4.0 (5.0)	20	140M-C2E-C16	100-C23
	5.5 (7.5)	25	140M-D8E-C20	100-C23
	7.5 (10.0)	30	140M-D8E-C20	100-C23
	11 (15)	50	140M-F8E-C32	100-C43
600V AC – 3-Phase	0.75 (1.0)	6	140M-C2E-B25	100-C09
	1.5 (2.0)	6	140M-C2E-B40	100-C09
	2.2 (3.0)	10	140M-C2E-B63	100-C09
	4.0 (5.0)	15	140M-C2E-C10	100-C09
	5.5 (7.5)	20	140M-C2E-C16	100-C16
	7.5 (10.0)	25	140M-C2E-C16	100-C23
	11 (15)	40	140M-D8E-C25	100-C30

(1) Recommended Fuse Type: UL Class J, CC, T or Type BS88; 600V (550V) or equivalent.

(2) Refer to the Bulletin 140M Motor Protectors *Selection Guide*, publication 140M-SG001… to determine the frame and breaking capacity required for your application.

Bulletin 140M (Self-Protected Combination Controller)/UL489 Circuit Breakers

When using Bulletin 140M or UL489 rated circuit breakers, the guidelines listed below must be followed in order to meet the NEC requirements for branch circuit protection.

- Bulletin 140M can be used in single and group motor applications.
- Bulletin 140M can be used up stream from the drive without the need for fuses.

As a rule, it is not allowed to use the motor protectors even if they are certified as TYPE "E", as protector of inverters, **if they are not specified in the manual supplied by the drive manufacturer.**

1.9 Heater branch circuit

156

The *heater branch circuits* are the circuits that feed the heater resistors.

The present analysis contains a description of the required standards for the process heating, i.e. linked to the functioning of the machine, and not that linked to the heating of the environments *("fixed electric space-heating").*

The UL508A standard brings together the main NEC and CEC regulations and imposes:

- Branch Circuit Protection: this must be calibrated at 125% of the rated current of the element and must not be higher than 60 A: this entails the maximum current of an element must be 48 A.

  If there are heater circuits with currents higher than 48 A it is necessary to separate them into several subcircuits that respect the norms.In the panel a size/calibration protection above 60 A may be placed in the panel providing the separation into subcircuits occurs in "in the field" using BCPs of a suitable size.

- The capacity of the conductors must be higher than the rated current of the resistive load.The capacity of the conductors must be above the nominal current of the resistive load.

Exceptions to the 48 A limit are allowed for special applications: for example the heaters outside to meld show and ice or the immersed type for heating water or generating steam.

The NFPA 79 standard for *Industrial Machinery* (and relevant section of UL508A) requires the oversizing of the wires to 125% of the rated resistant current. **It is advisable to unify the design by adopting the oversizing of the wires to 125%** because it is required by some AHJs for all the applications

EXAMPLE

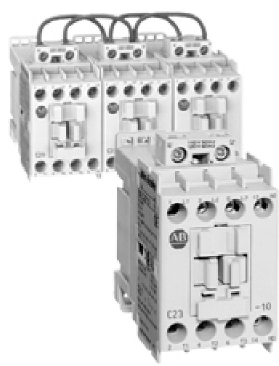
A three-phase heating resistance that absorbs 20 A is assumed.

The *branch circuit* protection must have sizes above 1.25 x 20 A = 24 A, consequently protection such as 25A fuses will be chosen.

The same calculation for the minimum capacity is also applied for the conductor inside the panel: the uprated cross-section is AWG 12 (25 A).

The resistive load command requires the use of a contactor sized in current. Solid state contactors are particularly suitable for this application: for example, use can be made of the **156-C20xA3,** three-phase with rated current of 20A and maximum voltage of 600V.

1.10 Lighting branch circuit



100L

500L

These are power circuits for lamps *used in the working process,* both for lighting (*"standard-duty"* lamps) and for other purposes (for example infrared lights for drying; *"heavy-duty"* lamps). These are not the panel's maintenance lights.

Also for this type of circuit UL508A gives an overview of the main regulations and distinguishes between:

- *Standard-duty* lamps (incandescent or fluorescent): the BCP must be calibrated at not more than 20 A; conductors must have a capacity above the size/calibration of the protection;
- *Heavy-duty* lamps (incandescent or infrared): il BCP must be calibrated at not more than 50 A; the conductors must have a capacity above the size/ calibration of the protection;

There are no limits on the power supply voltage.

Some differences are to be considered between the various norms as far as simply the lighting circuits are concerned:

a) the NFPA 79 standard for *Industrial Machinery* imposes a BCP with a size no greater than 15 A and a maximum supply voltage of 150 V; one side of the circuit must be grounded.

Supply can be provided through:
- transformers with separate winding down line from the main disconnect of the machine; the secondary must be protected;
- transformers with separate winding up line from the main disconnect of the machine; the secondary must be sectioned;
- one 120 V control circuit with its own protection against over currents.

b) the CEC makes a difference between the maximum size/calibration of the BCP on the basis of the power supply voltage: 20 A for voltages up to 347 phases higher than 347 V, 15 A for higher voltages.

The command of a lighting circuit requires contactors that are specifically approved for this purpose: the *"lighting contactor":* The sizing must be done on the basis of the current. One example of these contactors:

- 100L series for the IEC/UL/CSA contactors: there is one size and it is 20 A;
- 500L series for NEMA contactors: every size has a different current value, from 10 A to over 2000 A.

The maintenance lighting inside the panel is only dealt with in UL508A (as it is a regulation specifically for panels) and, or *Industrial Machinery,* in NFPA 79 (because of the "origins" in IEC 60204-1).

a) UL508A:
   - the lighting equipment must be approved in accordance to UL496 in the CCN OMTT or ONHR, or in accordance to UL1570 in the CCN IEUZ.
   - the voltage between conductors must be lower than 150 V.
   - the circuit must be considered as a power circuit and protected as already defined. One exception is permitted: if the power supply occurs at 120 V and it is derived downline from a control conformer with separate windings, then the circuit can be considered as a control circuit and managed as such.

b) NFPA 79 (and relative section of UL508A):
   - the lighting equipment must be approved (the previous UL approval classes of course apply);
   - less than 150 V; less than 15 A (as for all lighting circuits)
   - in addition to the cases already described, the maintenance supply circuit *inside the panel* can be derived from the secondary of a transformer with separate windings upline of the machine's main disconnect (and must not be sectioned or protected) or from the lighting circuit of the plant.

1.11 Appliance branch circuit

Any electrical user equipment mass produced to carry out a particular function is called an *appliance.* In general they are non industrial devices (for example household appliances).

Very often appliances are connected to a socket by means of a lead meaning that for sizing the rules already seen for the receptacles are applied.

In cases where the 'appliance is directly connected it is necessary to provide for a branch circuit, chosen with the following criteria (taken from UL508A):

- the type and size of BCP indicated on the markings of the device; in the absence of indications on the device, the following applies:
- if the *appliance* consists of at least one motor it must be protected as a motor (or group of motors) with the same power output;
- if the 'appliance does not contain a motor it is necessary to verify the rated current: if the current is less than 13.3 A the BCP must have a size that does not exceed 20 A; if this is not the case the size/calibration of the BCP must be smaller than 150% of the rated current.

1 Control Circuits

1.1 Definition of Remote control Circuit

In the *National Electrical Code* (art. 100 Part I) and in the *Canadian Electrical Code* (section 0) the following definition is given:

- ***Remote control circuit:*** *any electric circuit that controls any other circuit through a relay or an equivalent device.*

In the UL508A standard, Part 2 *Glossary,* the definition is: simplified and applied to the electrical panel:

- ***Remote control circuit:*** an electrical circuit that commands a control element (e.g. a contactor) and that does not supply power loads.

Single norms do admit different types of control circuits characterised by voltage, current and functions.

1.1.1 Classification of the circuits

The *National Electric Code* (NEC) distinguishes between three different types of control circuit:

- **Class 1:** general control circuit (up to 600 V, no limit in power VA); in some applications there is a requirement that the voltage and power be limited (30 V, 1000 VA).
- **Class 2:** control circuit powered by sources of limited power upon special approval: it is considered safe from the points of view of both direct contact and the risk of fire.
- **Class 3:** control circuit powered by limited power sources upon special approval, but with more power than it allowed for Class 2: it is considered safe from the risk of fire but not for the risk of direct contact.

Voltage and power limits for class 2 and 3 circuits are not given in the NEC because these are inherent to the limitations imposed on power sources in the relative construction standards.

The *Canadien Electric Code* (CEC) distinguishes between two different types of control circuit:

- **Class 1:** general control circuit: this can be limit in voltage and in power (30 V, 1000 VAC) or not (600 V, no limit for VA).
- **Class 2:** control circuit powered by limited power sources with special approval; distinctions are made on the base of the power voltage: up to 20 V, above 20 V up to 30 V, above 30 V up to 60 V and above 60 V up to 150 V.

It should be noted that the instructions for Class 1 circuits are similar in both NEC and CEC. Also these are very similar for Class 2 circuits: the CEC limits itself to giving a few additional instructions regarding the protections to adopt, while the NEC limits itself to referring to the approved components.

The UL508A links up with both NEC and CEC codes, but it gives additional instructions on how to ease the application.

- **Control circuit:** this is not clearly identified but it can be traced back to a Class 1 non limited circuit: there are no power or voltage limits (within the 600 V that specify the low voltage).
- **Class 2:** control circuit powered by limited power sources (generally 100 VA) with special UL approval (see for example the XLP 1606 Class 2)

1606

- **Low-Voltage Limited Energy Circuit:** is a type of control circuit limited in voltage and energy and is envisaged only by UL that reunites regulations of both Class 1 limited power and Class 2 circuits.

In the last edition of the NFPA 79 (2002) standard for *Industrial Machinery*, further restrictions were introduced for the circuits of control and command, in particular:

- **120 V** as a maximum voltage limit in alternating current and 250 V in direct current;
- **transformer with separate windings** for the 120V control circuit power derived from greater voltage power circuits.

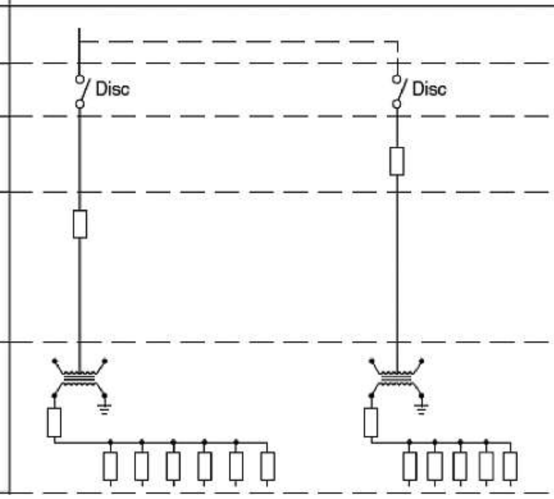
1.2 Control circuits

The control circuits (remote control) are considered to be the circuits that power and control loads like:

1. A pilot light shall comply with the Standard for Industrial Control Equipment, UL 508, and a miscellaneous lamp holder shall comply with the Standard for Edison-Base Lampholders, UL 496;
2. An electrically-operated valve shall comply with the Standard for Electrically Operated Valves, UL 429;
3. A solenoid shall be evaluated for the intended use;
4. A time-indicating or time-recording device, including an hourmeter, or a synchronous motor shall comply with the Standard for Time-Indicating and -Recording Appliances, UL 863;

5. An electrically operated counter shall comply with the Standard for Time-Indicating and -Recording Appliances, UL 863;
6. An audible signal appliance, including a horn, bell, or buzzer, shall comply with the Standard for Audible Signal Appliances, UL 464; and
7. A coil or input circuit to another control circuit switching device or to a load controller shall comply with other component requirements in this standard.

Reference	Control circuit connections
Supply NEC 70, Article 670	
Disconnecting means Chapter 5	
Main overcurrent protection (when supplied) 7.2.2; 7.2.3; 7.2.10	
Overcurrent protection, 7.2.7; 7.2.10	
Control circuit and special control protection cond., 7.2.4 trans., 7.2.7 undervoltage, 7.5 power supply, 7.2.12	



Caution: *the lighting lamps and the fans for electrical panels are considered to be control circuits. If these components are installed in the field (outside the electrical panel) they should be considered power circuits instead.*

1.3 Control circuit:

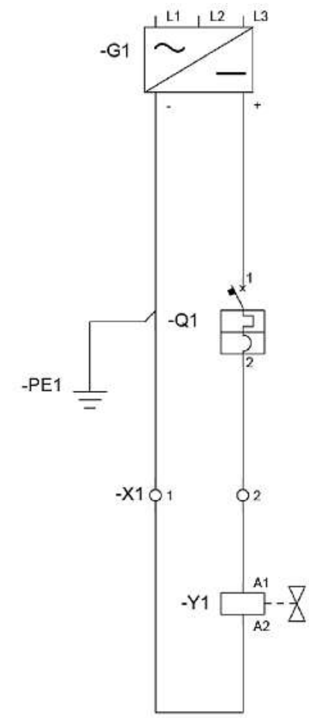
As already said, a general control circuit does not have voltage or power limits. It can be derived directly from the power circuits without the need of a transformer.

The powering of the control circuit can be obtained in two ways:

1. Directly from the general distribution inside the panel by installing a special branch circuit protection;
2. Down line from a pre-existing BCP.

The main standards (NEC, CEC) in no way require the connection of the control circuit on one side to the equipotent circuit, but it does not forbid it either.

NFPA 79 for *Industrial Machinery* on the other hand picks up again on the obligation to use a transformer with separate windings and with maximum voltage not above 120 V: one side of the circuit can be connected to the equipotent circuit.



In the definition of the individual components in a control circuit, reference is made to a general direct current circuit with one side connected to the equipotent protection circuit. A distinction is made between:

Supply: power source, in this case a power supply unit (but also a transformer).

Overcurrent Protection: overcurrent protection, in this example an supplementary protection 1492 –SP (but also a fuse).

Internal conductors/cables inside the panel

Terminal: interface terminal between the panel and on the machine

Load: load, in this example a solenoid valve (but also a coil or something else)

External: conductors/cables outside the panel

1.3.1 Load

The UL508A definition of the control circuit is an "electrical circuit that commands a control element (e.g. a contactor) and that does not feed power loads".

In paragraph 46 the standard lists the main loads that can be inserted in a control circuit: coils (of the contactors), solenoid valves, general meters, sounders and light signals. The solenoids, i.e. the coil of non contactors, should be assessed case by case.

Motors, lighting and resistors are never control loads. In reality, under certain conditions, panel maintenece lights and panel cooling fans can be considered as control circuit.

If one side of the control circuit is connected to the equipotent protection conductor, it is compulsory to connect one of the load connection terminals directly to this side.

1.3.2 External Wire

The conductors outside the panel follow the same rules given for power conductors, except that for the calculation of the section.

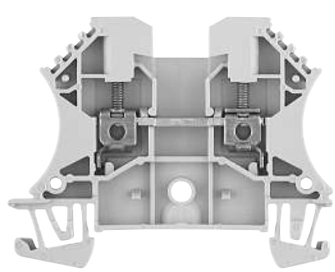
For the control circuits it is sufficient for the cable capacity not to be less than the rating of the Overcurrent Protection either up line or in the case of control transformers with protection on just the primary, less than the rated current of the transformer's secondary.

For the capacities of the external conductors it is advisable to take table 28.1 of UL508A as a reference. For the control conductors the use of correction factors is not required.

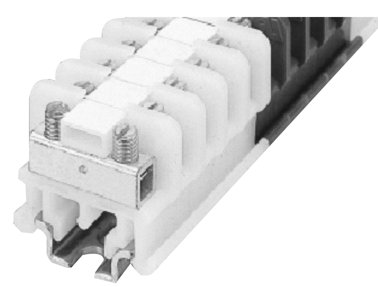
The minimum cross-section is not clearly defined in UL508A, even though AWG 14 "is suggested". Nonetheless both the NEC and the CEC have AWG 18 as minimum values for "laid" conductors (as usually happens on the machine) and AWG 16 for conductors in raceways.

The power conductors inside the same raceway or tube (conduit) should be insulated for the maximum voltage present; if one of the conductors is not insulated or is insulated for a lower voltage, it is necessary to distance it (at least 6.4 mm) or isolate it.

1.3.3 Terminal Block



1492



1492C NEMA

The terminal block for field wiring should be approved for use in an industrial environment and should be compatible with both external and internal conductors.

UL508A requires the terminal blocks installed to accept wire size of at least AWG 14, but in reality terminal blocks are also accepted for smaller wire size as long as one of the following conditions are accepted.

- the terminal block accepts AWG 14 conductors and smaller cross/sections: no particular prescriptions;
- the terminal block accepts only wire size smaller than AWG 14: it is necessary to indicate on the electrical diagrams or with a tag at the side of the terminal block, the maximum cross-section that it can accept. This is to avoid that, at a later date, the conductors of the control circuit being replaced with others, not compatible with the terminal block.

The *Class 1* circuit terminal block should be clearly indicated with a *marking.*

EXAMPLE

A control circuit made of AWG 18 cross section conductors is assumed.

If the interface terminal block accepts a AWG 18 – AWG 14 cross-section interval, one can go ahead regularly; if on the other hand the terminal block only accepts sections AWG 18 – AWG 16 then the maximum cross-section to be used should be indicated, for example on the schematics.

1.3.4 Internal Wire

The conductors inside the panel follow the same rules given for power conductors, except for the calculation of the section.

For the control circuits it is enough for the cable capacity not to be smaller than the rating of the protection upline or in its absence to the nominal current to the secondary of the control transformer.

For the capacities of the external conductors it is advisable to take table 28.1 of UL508A as a reference.

The operating temperature of the conductors is 90°C for wire size above AWG 16 and 60°C for conductors with cross sections the same as or lower than AWG 16 (it should be remembered however that a AWG 16 to 60°C conductor cannot be used for power circuits).

The minimum cross-section to be used for the internal control circuits is in both texts AWG 18, but only wire size lower than AWG 30 are allowed for wiring for PLC or static components (semi conductors and/or electronic). In UL508A table 38.1 shows the capacities allowed for conductors lower than AWG 18.

All the control circuit conductors inside the same raceway should be insulated for the maximum voltage present if one of the conductors is not insulated for a lower voltage, it is necessary to distance or isolate it.

1.3.5 Overcurrent Protection

1492-SP

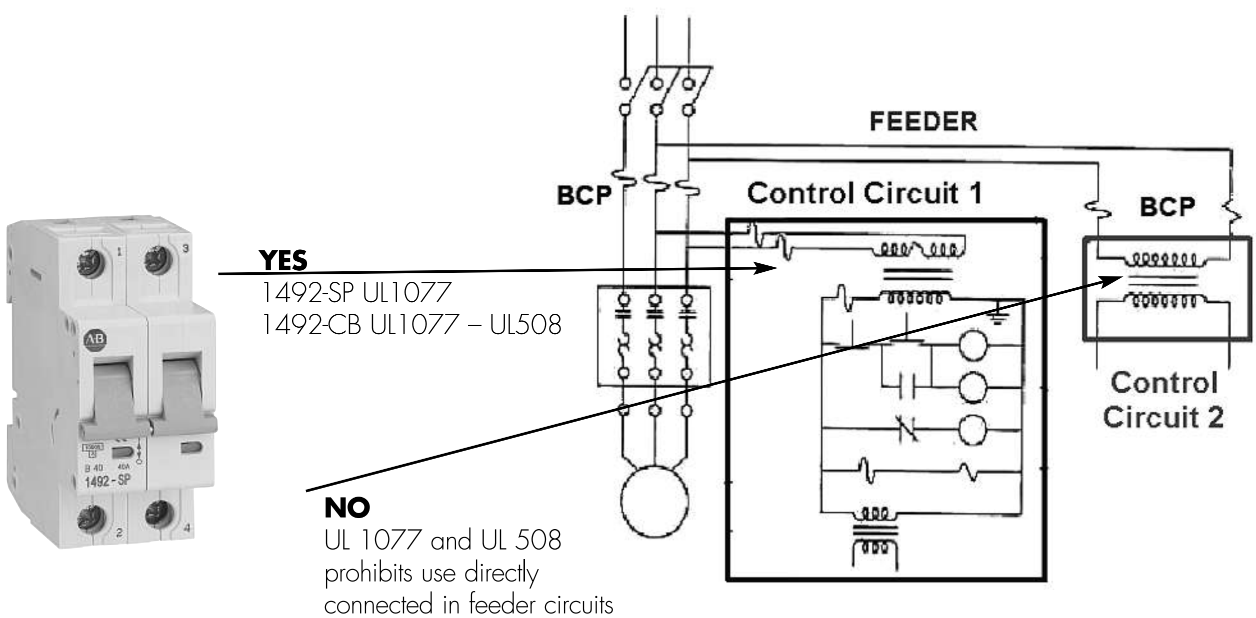
140F

The choice of overcurrent protection depends first and foremost on how the control circuit is powered:

1) Downline from a pre-existing BCP (Branch Circuit Protection).

2) Directly from the general distribution inside the panel by installing a special branch circuit protection;

The above mentioned circuits will be called ***Control downline of a BCP (shown in blue)*** and ***Control Circuit derived directly from the feeder (shown in red), respectively***



1) *Control Circuit* ***down line of a BCP***

The control circuit is derived down line from a *branch circuit* protection that already exists (UL 489 fuses or circuit breaker, in this example the BCPs are motor start fuses).

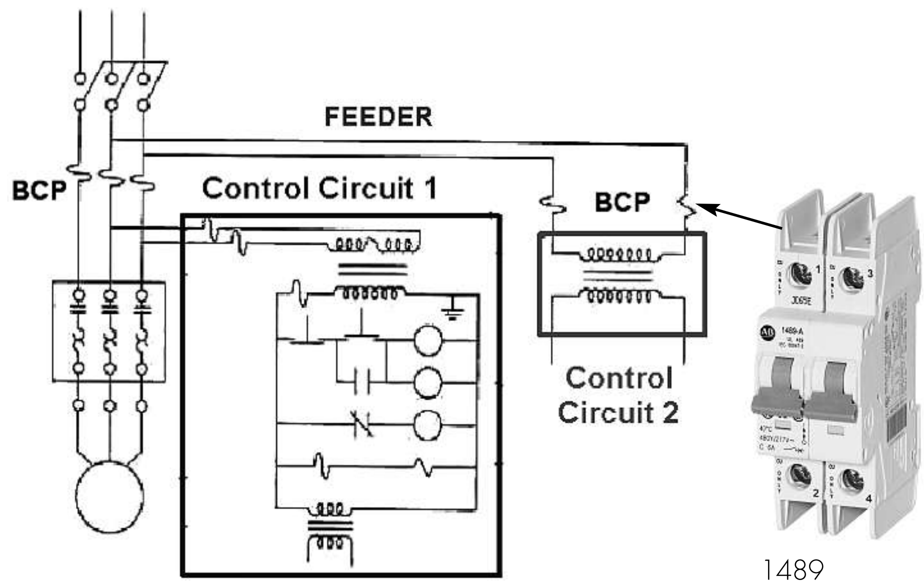
The BCP guarantees protection from short circuit of the feeder circuit; <u>the control circuit begins at the point where the relative conductors are derived.</u> All the overcurrent protections down line are part of the control

circuit and can be either devices suitable for the *branch circuit (UL508),* or protections called *"supplementary":* in particular *"supplementary fuses"* and *"supplementary protector"* (miniature circuit breaker, for example in accordance with UL1077, such as the **1492-SP).**

2) *Control Circuit* ***derived directly from the feeder***

   The control circuit is derived directly from the general powering *(feeder)* of the panel. In accordance with the North American standard definitions, the derivation is a power circuit *(branch circuit)* that, in its turn has the control circuit as a "load"

   The rules require to install a protection, of *branch circuit,* against the short circuit: the real control circuit begins down line from the BCP in which both devices suitable for the *branch circuits* or supplementary protections can be installed.



1489

The BCP connected to the feeder should have a rating that is not more than 20 A.

Inside the control circuit the standards require the use of an overcurrent protection (either *branch* or *supplementary)* in given points:

- in the case of a *Control Circuit* ***derived from the BCP***, down line of the pre-existing *branch circuit;*
- <u>always,</u> in the derivation points of conductors with a smaller cross-section.

The rating of the protections is chosen on the basis of:

– specific circuit requirements (as in *the low-voltage limited energy circuits);*

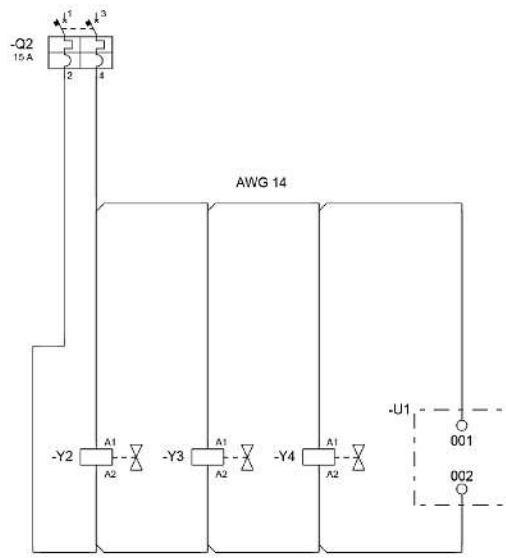
– control circuit conductor capacity;

– restrictions on the markings of the devices down line.

It is not necessary for a single protection to meet all the conditions listed, but it is possible to co-ordinate several protections to achieve this purpose, vertically and horizontally.

The North American standards require the protection of all the conductors that are not connected to the equipotent circuit.

EXAMPLE



A general control circuit is assumed to be derived of a special *branch circuit* Q2 protection down line, for example a circuit breaker (UL489) **140U-H2C3-C15** of 15 A or **1489-A2C-150**, that protects a solenoid valve assembly (Y1,Y2,Y3) and an electronic component (U1).

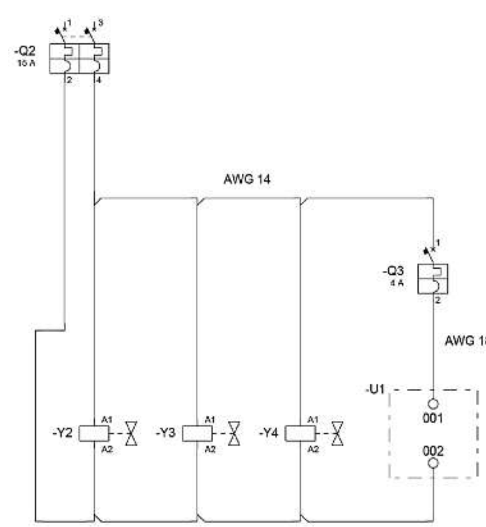
From table 29.1 the protected BCP cross-section, or AWG 14 (20 A) is obtained.

If the wiring is all made with AWG 14 and no component imposes particular restrictions, the circuit represented is correct and does not require anything else.

It is now assumed that the U1 component imposes the use of a 4A protection, in the marking, or in the instructions.

There are two solutions:

- to limit the entire circuit by replacing the BCP Q2 15 A with another of 4 A
- to insert a further Q3 4 A *supplementary* protection that protects just the conductor supplying U1. For example a **1492-SP1C040,** supplementary protection (UL1077 approved) can be used. Furthermore, down line from the Q3 protection it is possible to wire with a AWG 18 and 7A capacity conductor.



The first solution makes it possible to save a component, but limits the possibilities of the control circuit.The second solution cuts in locally respecting the requirements of component U1.

1.4 Special prescriptions for Control Circuit class 1

If the control circuit is derived downline from a *branch circuit* protection that already exists, *an overcurrent protection* should be installed at the point of derivation of the control circuit conductors.

For the equipping of general machines UL508A it is required to install a protection, sized in accordance to the general rules previously listed.

If, however, the circuit has been derived in a *motor branch* circuit two exceptions are admitted:

1. if the control circuit is still confined inside the control panel (for example the command push buttons are mounted on the metal work), it is protected from over currents by the *BCP motor* (without additional protections) if the values shown in table 41.1 of UL508A are respected.

Control circuit wire size		Maximum protective device rating, amperes
AWG	(mm^2)	
22	(0.32)	12
20	(0.52)	20
18	(0.82)	25
16	(1.3)	40
14	(2.1)	100
12	(3.3)	120

2. if the control circuit leaves the panel (for example in the case of remote pushbutton control station) it is protected against the over currents by the *motor BCP* (without additional protection) if the values defined in table 41.2 of UL508A are respected.

Control circuit wire size		Maximum protective device rating, amperes
AWG	(mm^2)	
22	(0.32)	3
20	(0.52)	5
18	(0.82)	7
16	(1.3)	10
14	(2.1)	45
12	(3.3)	60

Standard CSA 22.2 #14 also makes a similar exception: if the control circuit leaves the panel it is not necessary to have an additional *overcurrent protection* if the *motor BCP* has a rating that is no more than 300% the capacity of the conductors that, in their turn, should not be lower than 15A.

In the case of *Industrial Machinery* the NFPA 79 standard (and the relative section of UL508A) require the over current protection always to be installed and the sizing not to be above the value in table 66.4 of UL508A on the basis of the control circuit conductor cross-section, the BCP and the positioning of the components connected to the circuit.

In this regard it should be remembered that the control circuits can be derived directly (down line of an already existing BCP) only from the power circuits with voltage no more than 120 V.

Conductor size		Control circuit overcurrent device, amperes	Branch circuit overcurrent device, amperes	
AWG	(mm^2)		Control in wire panel	Remote control
larger than 14	(larger than 2.1)	equal to wire ampacity	400 percent of wire ampacity	300 percent of wire ampacity
14	(2.1)	20	80	60
16	(1.3)	20	40	20
18	(0.82)	20	25	20

EXAMPLE

A derivation of a control circuit down line from a BCP is assumed for a woodworking machine, *Industrial Machinery*. The circuit is confined within the panel and the BCP has a size of 25 A.

The circuit is made with a AWG 16 cable that, in accordance with tab. 28.1 of UL508A, carries 10 A.

The control circuit protection should not be greater than 10 A, but in the hypotheses advance it is possible for it not to be more than 20 A (and not 10 A).

If in the same conditions the control circuit were extended beyond the control panel the conditions in table 66.4 would no longer be respected. Two solutions are given:

- using a BCP of 20 A and refer to the conditions in which the table is being applied;
- using a 10 A protection and respecting the general rule (without applying table. 66.4).

1.5 Power Supply

The power supply of a control circuit can be a transformer for the circuits in alternating current or a rectifier for direct current circuits.

<u>The components should be approved by an NRTL for the envisage use.</u>

a) ***Switching* Mode power supply units:** should be approved for use in the industrial field.

UL508A also allows the use of power units for *Information Technology* that have passed a special over-temperature test. There will be a double marking: UR as *Information Technology Equipment (I.T.E.)* and UL as *Industrial Control Equipment (Ind. Cont. Eq.)*.

In the absence of the over-temperature test the component can be used, but the output current must be downgraded to 50% (that is to say a 10 A power unit should be limited with a special 5 A protection).

The protection of the power units should be done in accordance to the indications given in the instructions, making sure however that the components envisaged are suitable at the point of installation in accordance with CEC or NEC (see the overcurrent protection).

Note: ***All the Rockwell Automation power supplies in the 1606-XL Family are certified for industrial environments and are not subject to downgrading or to limitations!***

b) **Transformers / autotransformers:** the general *Class 1* control circuit does not require the separation between the windings (as already mentioned, only NFPA79 for *Industrial Machinery* imposes the use of the transformer).

The protection of the transformers and autotransformers should follow the rules given in the specific section.

1.6 Control Circuit Class 2

The main advantage of Class 2 circuit is the possibility given by UL508A to use non-approved components: this is however only applicable to internal conductors and control circuit components.

This is very often the only way out allowed to those using components, for example electronic cards, customised or own products, that could be challenged by the AHJs. Alternatively these components would need to be approved; such thing requires time and a non-justifiable expenditure.

1.6.1 Power supplies

The control circuits *Class 2* are fed by sources intrinsically limited. In particular UL508A imposes

1. transformers: CCN XOKV, XOKV2 (UL 1585 *"Class 2 transformer");*
2. transformers: CCN NWGQ, QQGQ2 (UL 1950 *"Information Technology Equipment")* only if use in Class 2 circuits is expressly indicated in *the marking.*

All the derived circuits down line of a *Class 2 supply* are to be considered *Class 2* circuits if properly wired.

1.6.2 Overcurrent Protection

Protections are not needed down line from the power source because the circuit is self/protected (there might be some few rare exceptions in the case of the use of conductors or components with particular characteristic).

Up line from the *supply,* the protection should be suitable for the point of installation (only BCPs are derived directly from the general *feeder, overcurrent protection* if we derive from a pre-existing BCP, down lines) and it should respect all restrictions imposed on the *marking* or instructions.

1.6.3 External Wiring and Terminal

The conductors on the machine of *Class 2* circuits should be approved; in addition they should be separated (with the use of special accessories) or isolated (minimum distance 50.8 mm) from the conductors of all the other non *Class 2* circuits.

The panel-on machine interface should follow the same provisions valid for the terminal blocks of a general control circuit (for example the limits on the cross-section that can be connected): in opposite cases the terminal blocks should be separated from of all the other circuits (not *Class 2).*

The *Class 2* circuit terminal block should be clearly indicated with a *marking.*

If this instruction is not respected the circuit goes automatically to *Class 1,* losing all the relative advantages.

1.6.4 Internal Wiring

The *Class 2* approved conductors should be separated or isolated from the conductors of the other circuits (not *Class 2)* unless they are insulated for the maximum voltage present.

It should be noted that if internal non approved conductors are used (for example N07V-K or H05V-K), what has been said above is no longer applicable and it is necessary to separate or segregate these conductors.

1.7 Low-Voltage Limited Energy Circuit

The *Low-Voltage Limited Energy* circuit has similar characteristics to those of a *Class 2* circuit and has been introduced into the UL508A by the Underwriters Laboratories unifying instructions for the circuits in *Class 1 and* limited in energy to 100VA as in *Class 2.*

As also for the *Class 2,* in these circuits it is possible to use non-approved components, loads and wiring down line from the limiting protection devices i.

The *Low-Voltage Limited Energy* circuit is easier to implement inside equipment than a *Class 2,* and is therefore the most "convenient" method for using customised or self made non approved components like electronic cards, proves.

The maximum voltages allowed are **30 V effective** in alternate current and **42,4 V** in direct current.

1606XL

1492-SP

1.7.1 Supply

The *Low-Voltage Limited Energy* circuits do not require specially approved power sources, but only that the galvanic separation of the power circuits is assured. In particular UL508A imposes:

1. Separate windings and transformers: CCN XPTQ, XPTQ2, XQNX and XQNX2 (UL506 *"Specialty Transformers"* e UL1561 *"Dry-Type General Purpose and Power Transformers");*
2. transformers: CCN QQAQ2: a CCN collection including in particular QQGQ2 (UL60950 *"Safety of Information Technology Equipment");*
3. Other sources with separate secondary: several types but in particular CCN NMMS and NMMS2 (UL508C *"Power Conversion Equipment");*

4. batteries;
5. Current transformers: CCN XODW2 (UL506 *"Specialty Transformers");*
6. Current transformers with 5 A secondary: approved or otherwise.

1.7.2 Overcurrent Protection

To assure that the circuit power is limited it is necessary to install an *overcurrent protection* down line from the *supply* dimensioned as in 43.1 of UL508A

Open-circuit secondary voltage, volts (peak)	Maximum overcurrent device, amperes
0 – 20	5
20.1 – 42.4	100/V[a]
[a] Where "V" is equal to the peak or dc open-circuit secondary voltage.	

It is known that in the calculation of the maximum protection size the peak value of the voltage should be applied (V_P) and not the effective value (V_{RMS}). Thus for a 24 V circuit we should consider two cases:

- direct current: $V_P = V_{RMS} = 24$ V

$$\frac{100}{24} \cong 4{,}17A$$

- alternating current:

$$V_P = \sqrt{2} \cdot V_{RMS} = 1{,}41 \cdot V_{RMS}$$

$$V_P = 1{,}41 \cdot 24 \cong 34V$$

and therefore

$$\frac{100}{34} \cong 3A$$

Circuits down line from the current transformers with (TA) with 5 A secondary are considered self protected.

It is not required for each *Low-Voltage Limited Energy* circuit to have its own power source but it is sufficient that the power of each is limited.

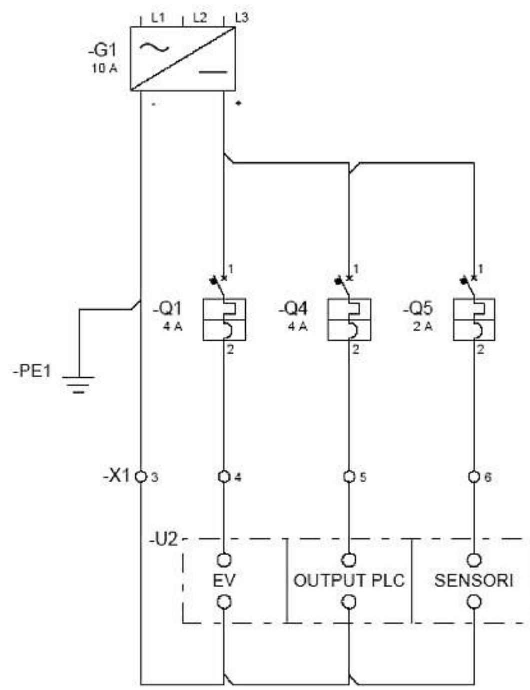
EXAMPLE

Let's say there is a 24 V control circuit in direct current with absorption of around 10 A. The components of the circuit are partially non approved

A choice should be made: replace all the non approved components with equivalent approved components or place them in *Low-Voltage Limited Energy* circuits. The first solution is usually not possible while it is generally possible to split loads over several different circuits (for example coils on one circuit and solenoid valves on another).

In this example it is assumed that the components are split up into three circuits. To enjoy the advantages of the *Low-Voltage Limited Energy* it is not necessary to

have three different power supplies but a single 10 A feed can be used (for example **1606-XL240E-3,** three-phase power unit) with three overcurrent protections down line (e.g. *supplementary protector* UL1077) graded to values of not more than 4 A: two at 4 A (for example **1492-SP1C040)** and the last one at 2 A *e.g. **1492-SP1C020).**



The three circuits derived down line from the protections respect all the conditions to be defined *Low-Voltage Limited Energy.*

It would have also been possible to realise *Class 2* circuits, but in the is case the intrinsic limitation of the power source would have forced three approved power units of *Class 2* to be used. To that respect however it should be remembered that Class 2 circuits are provided for both by NEC and by CEC, while the *Low-Voltage Limited Energy* circuit is only provided for by UL, even though it is commonly accepted by North American AHJs.

1.7.3 External Wiring and Terminal

The same prescriptions adopted for the *Class 1* circuits apply both for the external wiring and for the terminal blocks.

The approved conductors of the *Low-Voltage Limited Energy* circuit and those of the other circuits, inside the same raceway, <u>should be insulated for the maximum voltage present;</u> if one of the conductors is not insulated or it is insulated for a lower voltage, it should be distanced (at least 6,4 mm) or isolated. The isolation/separation is necessary in the case of non-approved conductors

The terminal block should be clearly indicated as *Class 1* with a special *marking.*

1.7.4 Internal Wiring

Approved conductors of *Low-Voltage Limited Energy* circuits should be separated or isolated from conductors of the other circuits unless they are insulated for the maximum voltage present.

It should be noted that (as for *Class 2* circuits) if internal non approved conductors are used for example N07V-K or H05V-K, what has been said above is no longer applicable and it is necessary to separate or isolate these conductors.

1.7.5 Circuits and components excluded from class 2 and Low-voltage limited-energy circuits

Attention to the product:

- Safety devices like immaterial safety barriers, safety limit switches, sensitive edges etc.
- motors & power loads, inverters, 24v step motors, etc.

Even if inserted and connected to power sources in class 2 and/or Low-voltage limited Energy sources they should always be approved by an NRTL laboratory.

1.8 Transformer and self transformer protection

NEC, CEC and UL508A do not really make distinctions between transformers and self transformer, limiting themselves to preventing the use of the self transformer in some civil systems.There is no limitation placed on its use for adapting the input voltage to the electrical equipment panel.

Transformer protection follows in precise rules in the NEC and the CEC regardless of whether the use is power or control, while the UL508A makes a few distinctions.

The NEC and CEC are however different: the difference cannot be neglected because it is often the cause of non conformities in Canada, where stricter rules are applied.

1) **NEC** (and **UL508A**): it is possible to protect "only on the primary" or "on the primary and secondary".

The protection on the secondary can be omitted only in the case of transformers with primary and secondary with two conductors (i.e. single and dual phase) or in the case of three-phase transformers with delta-delta connection. In both cases secondary should be single (i.e. multiple windings on the secondary each require its own protections).

- only primary: the protection should be sized to values of no more than

Primary current I_1 [A]	Rating protection [percentage of I_1]
≥ 9	125 % [a]
< 9	167 %
< 2	300 %

[a] if the rating does not correspond to a standard value (see the publication prior to section "BCP") the one immediately above the one calculated is permitted.

Standard UL508A limits itself to increasing the percentage for currents to the primary below 2 A by imposing:

- Current transformers: 500%
- Power transformers: 300%

The conductor feeding the primary should have a capacity of no less than the rating of the protection, while the conductor to the secondary should have a capacity of no less than the rating of the protection to the primary multiplied by the ratio of primary-secondary transformation.

EXAMPLE

Let's take a single phase 450 VA transformer.

primary	V_{1N} = 240 V	I_{1N} = 1,88 A
secondary	V_{2N} = 24 V	I_{2N} = 18,8 A

The primary-secondary transformation ratio is 10.

The protection to the primary should not be more than 1.88 x 3 = 5.64. 5 A fuses are used.

The conductor to the primary should have a capacity of not less than 5 A: from table 66.1A using UL508A through over sizing a AWG 16 (8 A) is chosen.

The conductor to the secondary should carry at least 5 x 10 = 50 A. Table 29.1 of UL508A is used to select a AWG 8 (60 A), considerably greater than the AWG 14 (20 A) that would have been sufficient considering the single current to the secondary.

- primary and secondary: the protection should be graded to values of no more than

Primary		Secondary	
Current I1 [A]	**Rating protection [percentage of I1]**	**Current I2 [A]**	**Rating protection [percentage of I1]**
≥ 9	250 %	≥ 9	125 % [a]
< 9	250 %	< 9	167 %
< 2	250 %		

[a] if the rating does not correspond with a standard value (see the publication prior to section "BCP") the one immediately above the one calculated is permitted.

Standard UL508A limits itself to increasing the percentage for currents to the primary below 2 A by imposing:

- Current transformers: 500%
- Power transformers: 300%

The protection of the secondary can be obtained with a special component or with the sum of the ratings of the protections down line.

In the case of single phase control transformers with one side of the secondary connected to the equipotent circuit, it is sufficient a single protection positioned on the side not connected (exactly as in Europe).

The conductors to the primary and the secondary should have a capacity of no less than the rating of the relative protection.

EXAMPLE

The same single phase transformer of 450 VA as the previous example is considered.

primary V_{1N} = 240 V I_{1N} = 1,88 A

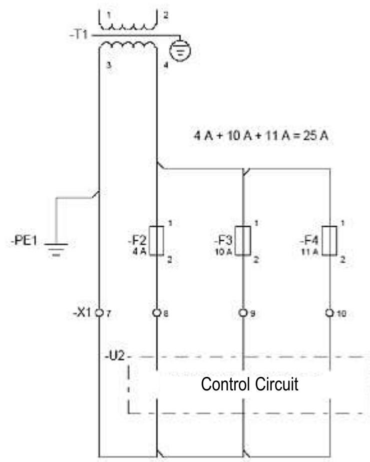
secondary V_{2N} = 24 V I_{2N} = 18,8 A

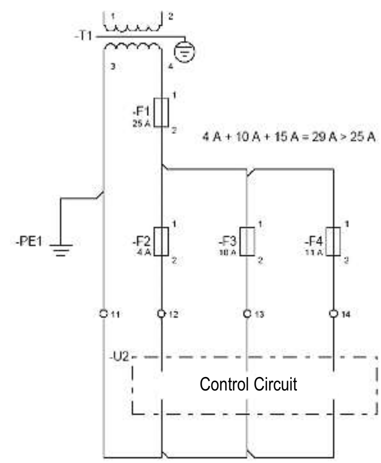
Let's say it is protected on the primary and on the secondary.

The protection to the primary should not be more than 1.88 x 2.5 = 4.7; 4 A fuses are used.

The protection on the secondary theoretically should not be more than 18.8 x 1.25 = 23,5 A. However, note [a] allows the use of the standard size immediately above and 25 A and fuses can be used.

If, say, the secondary powers three different circuits, each with their own protection (e.g. 4 A, 10 A and 11 A), the fuse can be omitted providing that the sum of the protection is not more than 25 A. If it is (e.g. 4 A, 10 A and 15 A) a dedicated component graded at 25 A should be used again.





The conductor to the primary should have a capacity of no less than 4 A: using UL508A table 28.1 over a AWG 16 (10 A) is chosen through over sizing.

The conductor to the secondary should have a capacity of at least 25 A. From table 28.1 of UL508A a AWG 10 (30 A) is chosen: this creates an absolute advantage compared with AWG 8 that would have been necessary for protecting just the primary.

2) **CEC:** it is possible to protect "only on the primary" or "on the primary and secondary". The protection "just at the primary" is only admitted for dry transformers up to 750 V with a single secondary, regardless of the type of connection.

- Only primary: the protection should be graded to a value of not more than 125% of the rated current to the primary. If the rating does not correspond with a standard value (see the publication prior to section "BCP") the one immediately above the one calculated is permitted.

  The conductor that powers the primary should have a capacity of no less than the rating of the protection while the conductor to the secondary should have a capacity of no less than 125% of the nominal current to the secondary.

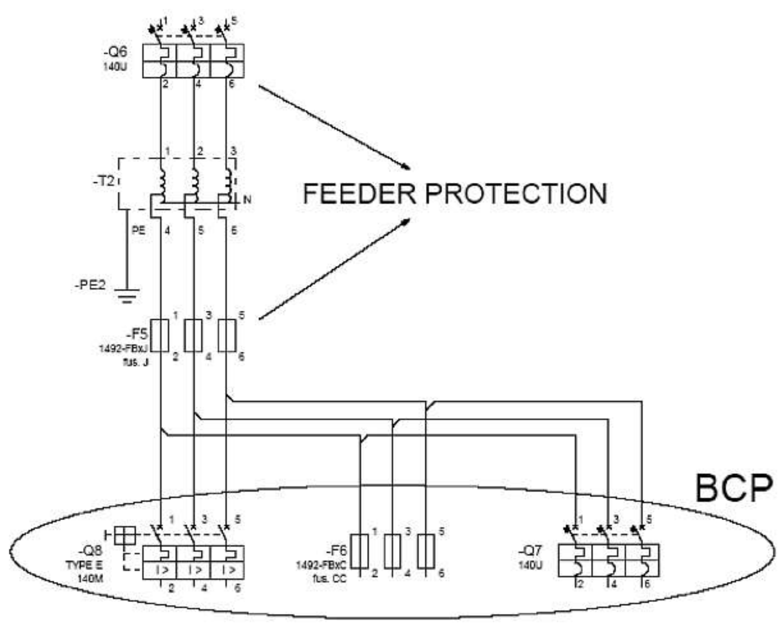
- Primary and secondary: the protection to the primary should be graded at a value of no more than 300% the rated current to the primary provided the secondary has protection graded at a value of no more than 125% of the rated current to the secondary.

The conductors to the primary and the secondary should have a capacity of no less than the rating of the relative protection.

1.8.1 Protections Allowed

The protection should be made with suitable components at the point of installation of the transformer/auto transformer.The most common can be specified

- self transformer on input to the panel to adapt the voltage: as already mentioned in the chapter on power circuits, the transformer is inserted inside the feeder and should therefore be protected with:
  - primary: fuses for the power circuits (for example CC or J fuses and relative fuse holders **140F, 1492-FB)** or molded case circuit breakers (e.g. **140-U);**
  - secondary: as for the primary unless the protection is the sum of the *branch circuit* protections (BCP).



- control transformer powered by the feeder:
  - primary: the protection of the transformer is for all intents and purposes a BCP, but special components **cannot** be used for motor starting such as combination motor controller or manual motor controller;
  - secondary: we are inside the control circuit, thus all components can be used including the *supplementary* protection (e.g. the miniature circuit breakers **1492-SP).**
- the control transformer powered down line with an existing branch circuit transformer: primary and secondary are already part of the control circuit thus all the components can be used including the *supplementary* protection (e.g. the miniature circuit breakers **1492-SP).** The protection to the primary can be omitted if the rating if the pre-existing BCP satisfies the sizing indicated above.

1.9 Control of the temperature in the panel

American and Canadian standards do not make any reference to specific over temperature tests of the panel but they require the control of the temperature in the panel to guarantee its full functionality.

The over-temperature can be avoided with fans, anti condense resistors and conditioners. The components in the conditioner system are considered power components and therefore part of one of the *branch circuit* already described:

- fans — ***motor branch circuit;***
- anti condense resistors — ***heater branch circuit;***
- conditioners — ***motor appliance branch circuit.***

In UL508A fans may be installed inside the control circuits provided that both the following conditions are respected:

- using approved fans: CCN GPWV2 (UL 507 *"Electric Fans")*. The use of these components implies automatically *low-voltage* use: in fact UL507 imposes, as maximum fan feed voltages, **30 V effective** in alternating current and **42.4 V** in direct current;
- deriving the control circuit downstream from a transformer/power supply unit that ensures electrical separation.

Industrial Machinery

1. NEC 2005 and article 670 on Industrial Machinery

In September 1941 the metal working machinery industry elaborated its first electrical standard to make machinery safer for operators, more productive and cheaper to maintain, as well as to improve quality and performance of electrical components.

In the same year and in order to analyse electrical problems related to machinery, the NFPA created a special electrical commission specialised in overcurrent protection and the control of industrial engines fitted to industrial machinery.

This commission, in collaboration with the manufacturers of machinery electrical equipment and Underwriters Laboratories, carried out a series of test and controls whose results differed with the requirements of the National Electrical Codes at that time.

The results were published in 1942 as an "amendment" to article 670 on Machine Tools of the National Electrical Code of 1940 and such article remained basically unchanged until the 1959 edition appeared.

Mistakenly, in 1940 other machinery manufacturers started to take article 670 as a reference when it had been initially drawn up exclusively for metal working machinery.

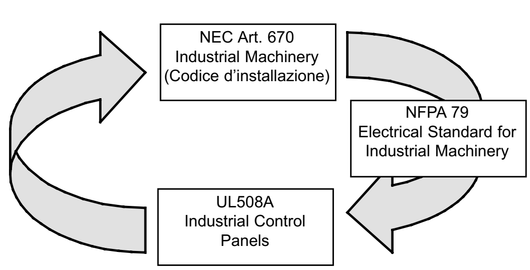
Then, in 1952, an electrical commission was established to try to gather all the special requirements for the production, handling and process machinery all in one NEC article.

This attempt failed and in 1956 a NFPA commission was established to limit the application of art. 670 NEC only to metal working machinery. This article remained however too limited; and it was so because a new standard that specified safety requirements not dealt with before was included.

In 1961 the NFPA 79 "Electrical Standards for machine tools" was officially introduced and subsequently revised in 1965, confirmed in 1969 and revised again in 1970, 1971, 1973, 1974, 1977, 1980, 1985, 1987, 1989, 1994 and the last edition in 2002 which is currently in force.

In fact in its first clauses, the National Electrical refers to NFPA 79 as the reference standard applicable to industrial machinery.

NFPA 79 Industrial Machinery refers to the UL508A standard on Industrial Control Panels as the primary reference standard, and so circle is completed as per North American legislation on electrical systems for industrial machinery:



1.1 Machinery categories in "Industrial Machinery" [1])

Industrial machinery refers to:

a) Metalworking machine tools, including machines that cut or form metal;

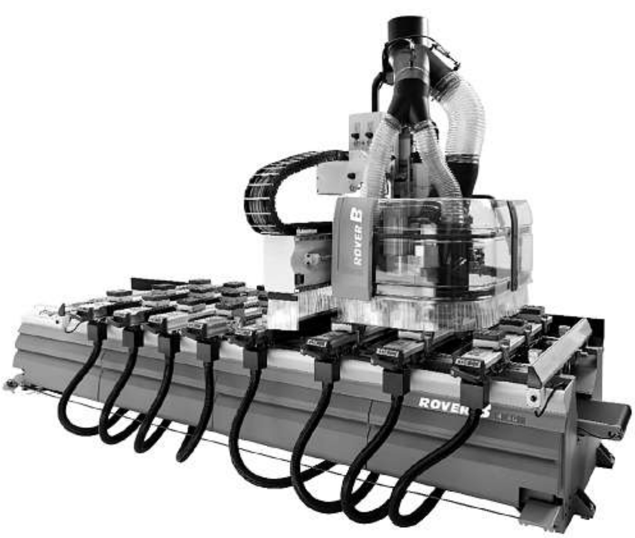
b) Plastics machinery, including injection molding, extrusion, blow molding, specialized processing, thermoset molding, and size reduction machines;

c) Wood machinery, including woodworking, laminating, and sawmill machines;

d) Assembly machines;

e) Material handling machines, including industrial robots and transfer machines; and

f) Inspection and testing machines, including coordinate measuring and in-process gauging machines.



[1]) This list is taken from UL 508A, clause 65.1

2. Special requirements

Besides all information presented and pointed out in the previous chapters for industrial machinery, both NFPA 79 and UL508A (clause 65) set out more restrictive specifications that must to be respected.

Particularly the main limitations can be summed up as follows:

- Use of some specific types of fuses
- Different feeder protection calculation
- Cable and wire: sizing and colours
- Different machine nameplate
- Obligation to calculate short circuit current

2.1 Fuses

A branch and feeder circuit fuse in industrial machinery is limited to Class RK1, RK5, J, T or CC; class H, K, and G, fuses shall not be used.

2.2 Sizing of the feeder overcurrent protection

A feeder overcurrent protection device in the panel is expressly required only for Industrial Machinery according to NFPA 79 (and section 66.7 of UL 508A), but its presence is also required in NEC and CEC, where sizing rules are provided.

The rating/setting must be selected and sized basing on the addition of:

a) Rating/setting of the protection for the largest BCPC
b) 125% of all resistive loads
c) 125% of the large motor load
d) All other loads that can operate simultaneously

2.3 Cables

There are 2 main differences as regards cables; the first type is connected with power conductors' minimum sizing that can be used in panels while the second deals with colours.

2.4 Minimum power cable section

Effective March, 2007, 16 and 18 AWG power conductors will ONLY be allowed under the Industrial Machinery section 66.5.4 with specific protection and will NOT be allowed under the general panel provisions.

2.5 Conductor colours

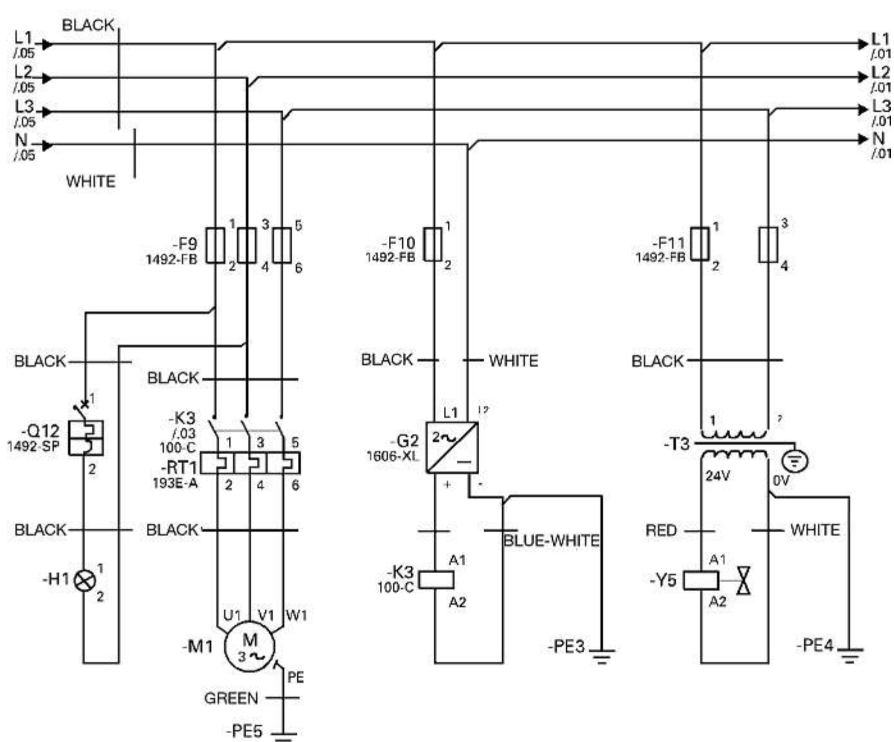
NEC and CEC (and UL508A in the general section) only define the colours for neutral and equipotential conductors:

- **white** or **grey**: neutral
- **green (green-yellow** also allowed): ground connection

All other conductors can be identified with any colour provided that the above colours are not used.

The **NFPA 79** standard for *Industrial Machinery* (and section 66.9 of UL508A) specifies cable colour:

- **black**: all the rated voltage conductors (both <u>power and control</u>)
- **white** or **grey**: for conductors in alternating current connected to the grounded circuit (mainly the neutral and the earth side of the AC control circuits)
- **green**: (**green-yellow** also allowed); ground connection
- **red**: AC control circuit with voltage <u>different</u> from the rated one (ungrounded)
- **blue**: DC control circuit (ungrounded)
- **blue-white**: DC control circuit *(grounded)*
- **yellow**: (**orange** also allowed); interlocking circuits powered upstream the main circuit breaker (grounded)
- **yellow-white**: interlocking circuits powered upstream the main circuit breaker *(ungrounded)*



3. Short Circuit Current Rating

3.1 Short Circuit Current Rating

3.1.1 National Electric Code Changes Overview

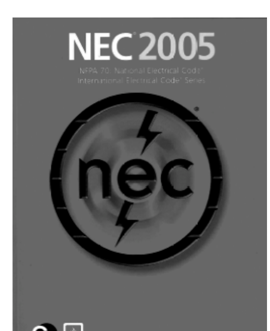
National Electrical Code Introduces Article 409 for Industrial Control Panels

In 2005, the National Electrical Code (NEC) introduced Article 409 for Industrial Control Panels requiring that panel builders and original equipment manufacturers (OEM) analyze and mark their panels with short circuit current ratings (SCCR).

Why Article 409 was developed?

Historically, industrial control panels have been evaluated under several different NEC articles, which have led to inconsistencies. Article 409 provides common construction and installation requirements. It also establishes a marking requirement for short circuit current ratings of industrial control panels.

The fine print note of NEC Article 409.110 references UL508A, Supplement SB as an approved method to evaluate the short circuit current ratings of their panel. As individual states adopt the 2005 Edition of the NEC, a thorough understanding UL508A, Supplement SB is essential.



NEC 2005 Code Book

NEC Article 409.110

An industrial control panel shall be marked with the following information that is plainly visible after installation:

1. Manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product can be identified.
2. Supply voltage, phase, frequency, and full-load current.
3. Short-circuit current rating of the industrial control panel based on one of the following:

   a. Short-circuit current rating of a listed and labeled assembly

   b. Short-circuit current rating established utilizing an approved method

   FPN: UL508A-2001, Supplement SB, is an example of an approved method.
4. If the industrial control panel is intended as service equipment, it shall be marked to identify it as being suitable for use as service equipment.
5. Electrical wiring diagram or the number of the index to the electrical drawings showing the electrical wiring diagram.
6. An enclosure type number shall be marked on the industrial control panel enclosure.

3.1.2 Determining Your Panel Short Circuit Current Rating

Per Section 409.110 of the NEC, there are two permitted ways to determine your panel short circuit current rating: purchase a previously listed and labeled assembly or establish the short circuit current rating of the panel using an approved method. For the latter, the only stated approved method is UL 508A, Supplement SB.

According to UL508A, Supplement SB4.1, there are three steps to analyze and mark your panel with a short circuit current rating:

STEP 1 Establish the short circuit current ratings of individual power circuit components.

STEP 2 Modify the available short circuit current within a portion of a circuit in a panel due to the presence of current limiting components.

STEP 3 Determine the overall short circuit current rating of the panel.

STEP 1

Establish the short circuit current ratings of individual power circuit components using one of the following methods:

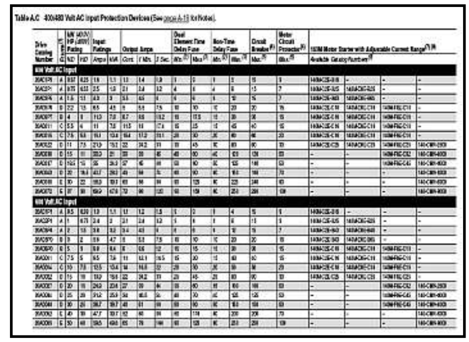
a) The short circuit current rating marked on the component or on instructions provided with the component;

Nameplate

USA/CND
Suitable for use on a circuit capable of delivering not more than XXX rms symmetrical amperes.

	XXX = 5,000		XXX = 100,000
	Fuse	Circuit Breaker	Class J or CC Fuse
Size	600 V max.	480 V max.	600 V max.
9	35 A	30 A	20 A
12	40 A	30 A	20 A
16	70 A	50 A	30 A
23	90 A	50 A	30 A

Installation Sheets



User Manual

Examples of short circuit current rating product markings on nameplates and in reference documents

b) The short circuit current rating determined by the voltage rating of the component and the assumed short circuit current rating from Table SB 4.1;

If the power circuit component does not have a short circuit current rating or has not been required to have a rating in the past, Table SB4.1 in UL508A, Supplement SB lists the assumed maximum short circuit current rating for unmarked products.

Table SB4.1
Assumed maximum short circuit current rating for unmarked components
Table SB4.1 effective April 25, 2006

Component	Short circuit current rating, kA
Bus bars	10
Circuit breaker (including GFCI type)	5
Current meters	[a]
Current shunt	10
Fuseholder	10
Industrial control equipment:	
a. Auxiliary devices (overload relay)	5
b. Switches (other than mercury tube type)	5
c. Mercury tube switches	
Rated over 60 amperes or over 250 volts	5
Rated 250 volts or less, 60 amperes or less, and over 2 kVA	3.5
Rated 250 volts or less and 2 kVA or less	1
Motor controller, rated in horsepower (kW)	
a. 0 – 50 (0 – 37.3)	5[c]
b. 51 – 200 (38 – 149)	10[c]
c. 201 – 400 (150 – 298)	18[c]
d. 401 – 600 (299 – 447)	30[c]
e. 601 – 900 (448 – 671)	42[c]
f. 901 – 1500 (672 – 1193)	85[c]
Meter socket base	10
Miniature or miscellaneous fuse	10[b]
Receptacle (GFCI type)	2
Receptacle (other than GFCI type)	10
Supplementary protector	0.2
Switch unit	5
Terminal block or power distribution block	10

[a] A short circuit current rating is not required when connected via a current transformer or current shunt. A directly connected current meter shall have a marked short circuit current rating.
[b] The use of a miniature fuse is limited to 125-volt circuits.
[c] Standard fault current rating for motor controller rated within specified horsepower range.

Table SB4.1 Assumed maximum short circuit current rating for unmarked components

c) The short circuit current rating for a load controller, motor overload relay, or combination motor controller that has been investigated in accordance with the performance requirements, including short circuit test requirements for standard fault currents or high fault currents specified in the Standard for Industrial Control Equipment, UL 508, and described in the manufacturer's procedure.

Part c) states that specific tested combination ratings can be used by a panel manufacturer if the combination ratings are included their UL procedure file. Rockwell Automation tests and certifies a wide-range of NEMA and IEC components to meet the requirements of NEC Article 409 and UL 508A, Supplement SB (See page 100).

STEP 2

Modify the available short circuit current within a portion of a circuit in a panel due to the presence of current limiting components as specified in SB4.3, when applicable;

This second step takes into account the effect of any current limiting devices in the feeder circuit. Current limiting refers to the ability of a protective device to clear a short circuit fault in less than one half cycle and typically within one quarter cycle. Current limiting devices will reduce the levels of Ipeak magnetic and I2t heat energies.

SB4.3 establishes the guidelines for three methods of using feeder components that limit the available short circuit current.These options include power transformers, Listed circuit breakers and fuses as described in these sections:

- SB 4.3.1: Branch circuits supplied by a power transformer with an isolated secondary.
- SB 4.3.2: Listed circuit breaker marked "current limiting" in the feeder circuit.
- SB 4.3.3: Branch circuits supplied by a Class CC, G, J, L, RK1, RK5 or T fuse in the feeder circuit.

These sections identify the feeder components that limit the short circuit current available and guidelines in applying them. For many years, fuses were the only protective devices that were considered to provide current limiting performance. Today, circuit breakers exist that can open high fault currents in just a few milliseconds, very comparable to fuses.These sections also identify the Ipeak, I2t and let-through values that must be used when applying a current limiting component.

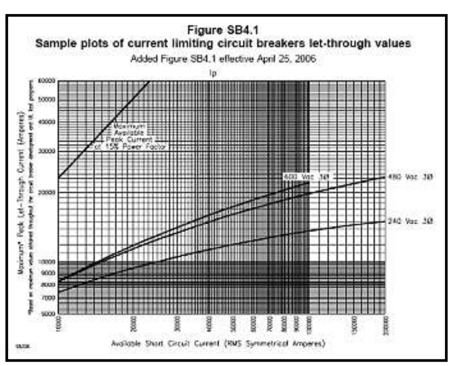


Figure SB4.1 Let-through values for current limiting circuit breakers from UL 508A Supplement SB

Table SB4.2
Peak let through currents, I_p, and clearing, I^2t, for fuses
Table SB4.2 effective April 25, 2006

Fuse types	Fuse rating amperes	Between threshold and 50 kA $I^2t \times 10^3$	Between threshold and 50 kA $I_p \times 10^3$	100 kA $I^2t \times 10^3$	100 kA $I_p \times 10^3$	200 kA $I^2t \times 10^3$	200 kA $I_p \times 10^3$
Class CC	15	2	3	2	3	3	4
	20	2	3	3	4	3	5
	30	7	6	7	7.5	7	12
Class G	15	–	–	3.8	4	–	–
	20	–	–	5	5	–	–
	30	–	–	7	7	–	–
	60	–	–	25	10.5	–	–
300 volt Class T	30	3.5	5	3.5	7	3.5	9
	60	15	7	15	9	15	12
	100	40	9	40	12	40	15
	200	150	13	150	16	150	20
	400	500	22	550	28	550	35
	600	1000	29	1000	37	1000	46
	800	1500	37	1500	50	1500	65
	1200	3500	50	3500	65	4000	80
Class J and 600 volt Class T	30	7	6	7	7.5	7	12
	60	30	8	30	10	30	16
	100	60	12	80	14	80	20
	200	200	16	300	20	300	30
	400	1000	25	1100	30	1100	45
	600	2500	35	2500	45	2500	70
	800	4000	50	4000	55	4000	75
Class L	800	10000	80	10000	80	10000	80
	1200	12000	80	12000	80	15000	120
	1600	22000	100	22000	100	30000	150
	2000	35000	110	35000	120	40000	165
	2500	–	–	75000	165	75000	180
	3000	–	–	100000	175	100000	200
	4000	–	–	150000	220	150000	250
	5000	–	–	350000	–	350000	300
	6000	–	–	350000	–	500000	350

Fuse types	Fuse rating amperes	Between threshold and 50 kA $I^2t \times 10^3$ RK1	RK5	Between threshold and 50 kA $I_p \times 10^3$ RK1	RK5	100 kA $I^2t \times 10^3$ RK1	RK5	100 kA $I_p \times 10^3$ RK1	RK5	200 kA $I^2t \times 10^3$ RK1	RK5	200 kA $I_p \times 10^3$ RK1	RK5
Class R	30	10	50	6	11	10	50	10	11	11	50	12	14
	60	200	200	10	20	40	200	12	21	50	200	16	26
	100	500	500	14	22	100	500	16	25	100	500	20	32
	200	1600	1600	18	32	400	1600	22	40	400	2000	30	50
	400	5000	5000	33	50	1200	5000	35	60	1600	6000	50	75
	600	10000	10000	43	65	3000	10000	50	80	4000	12000	70	100

* Value applies to Class T fuses

Table SB4.2 Let-through table for UL Listed fuses from UL 508A Supplement SB

Using high fault rated components can eliminate the need to apply feeder circuit current limiting provisions.This makes its simple to achieve a higher panel rating. See page 99 for more information on component high fault short circuit current ratings.

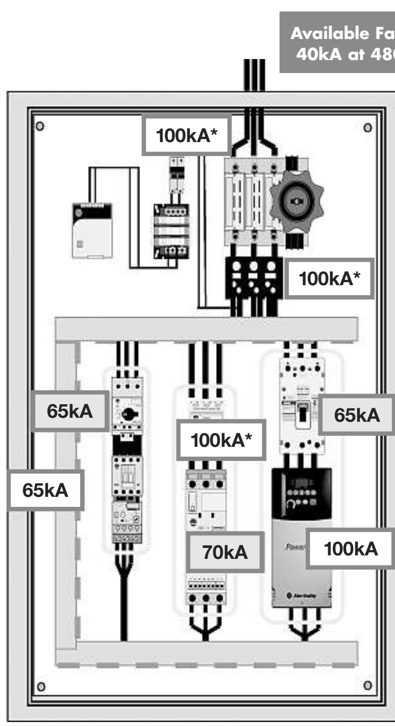
STEP 3

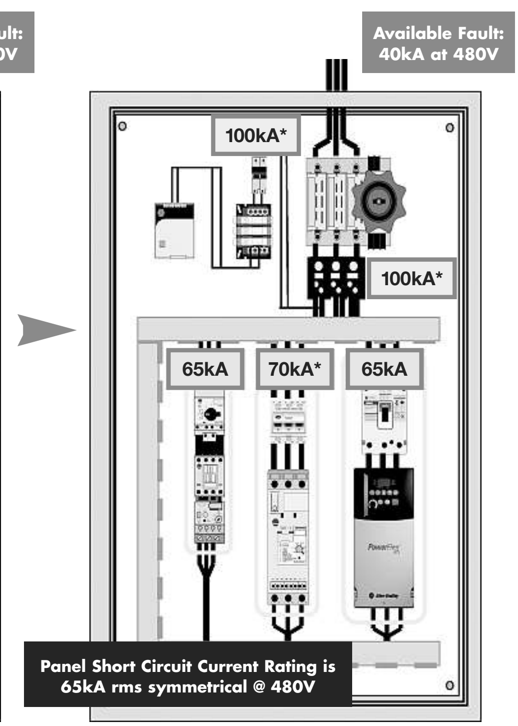
Determine the overall short circuit current rating of the panel as specified in SB4.4.

The short circuit current ratings of the individual components are compared to their branch circuit protective device.The smaller of the two ratings are applied to the line side of the branch circuit protective device. If a control circuit is located in a branch, then the overcurrent protective device for the control circuit must also be considered.

The guidelines for determining the short circuit current ratings of the complete panel can be found in SB4.4.4. For control panels with single branch circuits, the short circuit current rating of the panel is the rating of the branch.

Control panels with multiple branch circuits and feeder components are covered in clause c) The lowest short circuit current rating of all branch circuits, feeder components and control circuit overcurrent protective devices, connected to the feeder will determine the panel short circuit current rating.





The short circuit current ratings of the individual components are compared to their branch circuit protective device

The smaller of the two ratings, (highlighted in yellow) are applied to the line side of the branch circuit protective device

In this example, the lowest short circuit current rating of all branch circuits, feeder components and control circuit overcurrent protective devices connected to the feeder is 65kA.Therefore, the overall panel short circuit current rating is 65kA rms symmetrical at 480V.

* Values represent overcurrent protective device with fuses

3.1.3 High Fault Short Circuit Current Ratings

Although table SB 4.1 is used to determine the assumed short circuit current rating of unmarked components, it also provides a reference for the standard fault ratings of various products. Components with only these ratings may significantly limit the maximum attainable panel short circuit current rating.

High fault rated components have short circuit current ratings that exceed these values. High fault short circuit current ratings also eliminate the need to apply current limiting provisions in the feeder circuit. Using high fault rated components makes it simple to achieve a higher panel rating.

Rockwell Automation Component Solutions Provide The High Fault Short Circuit Current Ratings Needed By Today's Panel Manufacturers

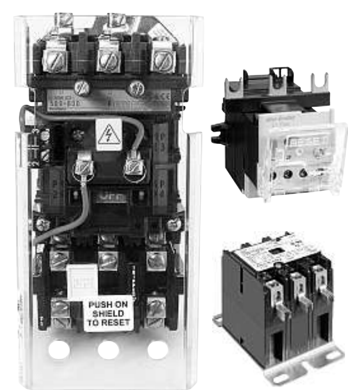
Rockwell Automation provides high fault tested UL/CSA listed combinations for branch and feeder circuits. These high fault ratings meet and exceed the short circuit current ratings required to cover the available fault current at panel installations. Here are a few examples of the high fault ratings you can achieve with Rockwell Automation power circuit components:

NEMA Bulletin 500 Line Contactors, Overload Relays & Starters

- Circuit Breaker combinations to 100kA 480V, 50kA 600V
- Fused combinations to 100kA 600V (Type 2)

IEC Bulletin 100 Line Contactors, Overload Relays & Starters

- Circuit Breaker combinations to 65kA 480V, 30kA 600V (Type 2)
- Fuse combinations to 100kA 600V (Type 2)



NEMA Starters and Contactors

SMC™ Soft-Starters

- Fuse Combinations to 70kA 600V

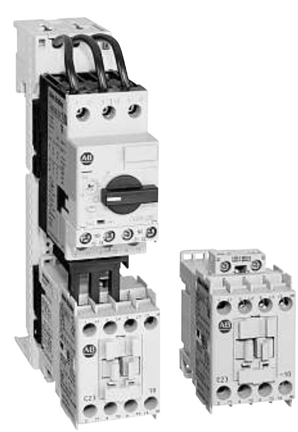
PowerFlex® Drives

- Circuit Breaker combinations to 100kA 480V
- Fused combinations to 200kA 600V

NEMA & IEC Fused Disconnect Switches to 200kA 600V

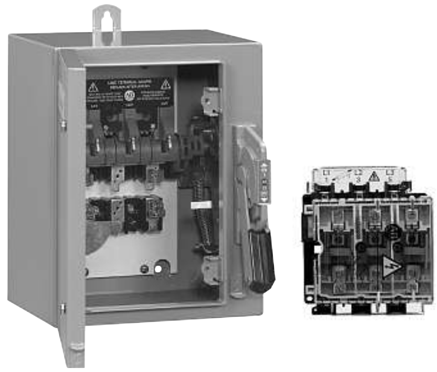
Power Distribution Blocks

- Fused combinations to 100kA 600V



IEC Starters and Contactors

SMC™ Flex Soft Starter



NEMA and IEC Fused Disconnect Switches

PowerFlex Drives

Power Distribution Blocks

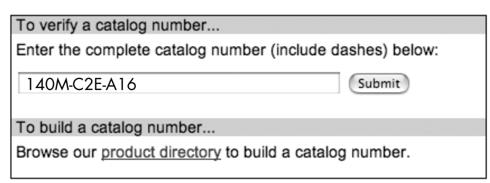
3.1.4 High Fault Component Short Circuit Current Rating Information Is Available Online

High fault short circuit current rating information can be easily accessed online at: http://www.rockwellautomation.com/products/certification/ul508a/

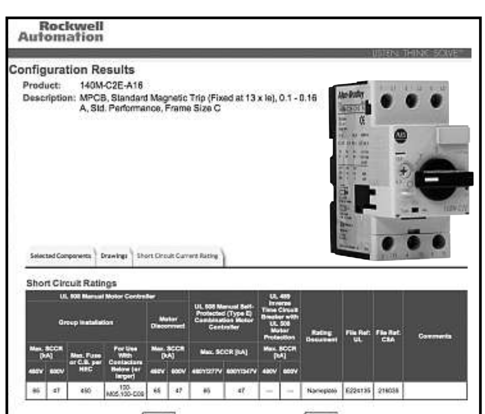
Rockwell Automation.com Website

Enter the catalog number and select "Submit" to attain short circuit current rating data for the identified component or browse the product directory if your catalog number is not known.

Catalog Number or Product Directory Selector Tool



View and download short circuit current rating information



High fault short circuit current ratings for an Allen-Bradley Bulletin 140M Motor Protection Circuit Breaker

NEMA Power Components

- Contactors
- Overload Relays
- Starters
- Disconnect Switches

IEC Power Components

- Motor Protection Circuit Breakers
- Motor Circuit Protectors
- Contactors
- Overload Relays
- Starters
- Disconnect Switches

Circuit Protection

- Molded Case Circuit Breakers
- Miniature Circuit Breakers
- Fuse Blocks

Connection Systems

- Bus Bar Mounting Systems
- Commoning Links
- Distribution Blocks

Soft-Starters

Drives

Servo Drives

3.1.5 Marking Your Panel

Once the short circuit current rating of the overall panel has been established, it must be marked on the panel. NEC marking requirements include the manufacturer's name or trademark and the basic information of supply voltage, phase, frequency, full-load current and the short circuit current rating. The label should be plainly visible after panel installation.

MANUFACTURER NAME________________________

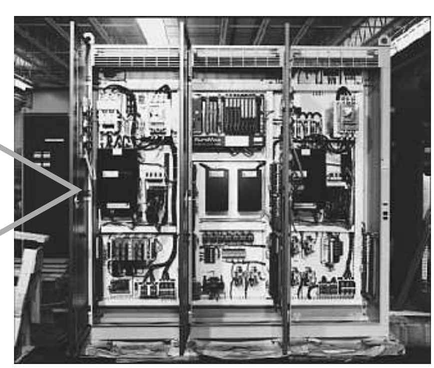
VOLTAGE______, PHASE_____, FREQUENCY_______

FULL LOAD CURRENT_______________________

SHORT CIRCUIT CURRENT RATING ______________

INDEX # OF ELECTRICAL WIRING DIAGRAM________

ENCLOSURE TYPE______________



Label should be plainly visible after installation*

*Additional markings may be required depending on the particular panel design and intended use.

www.rockwellautomation.com

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